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**Coats et al.**

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(54) **MODULAR CONFIGURABLE PAVING APPARATUS AND MODULAR CONFIGURABLE PAVING OPERATION SYSTEM**

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(51) **Int. Cl.**  
*E01C 19/00* (2006.01)  
*E01C 19/42* (2006.01)

(52) **U.S. Cl.**  
CPC *E01C 19/00* (2013.01); *E01C 19/42* (2013.01)

(58) **Field of Classification Search**  
CPC ..... E01C 19/00; E01C 19/42  
USPC ..... 404/83, 85, 93, 101, 104, 105  
See application file for complete search history.

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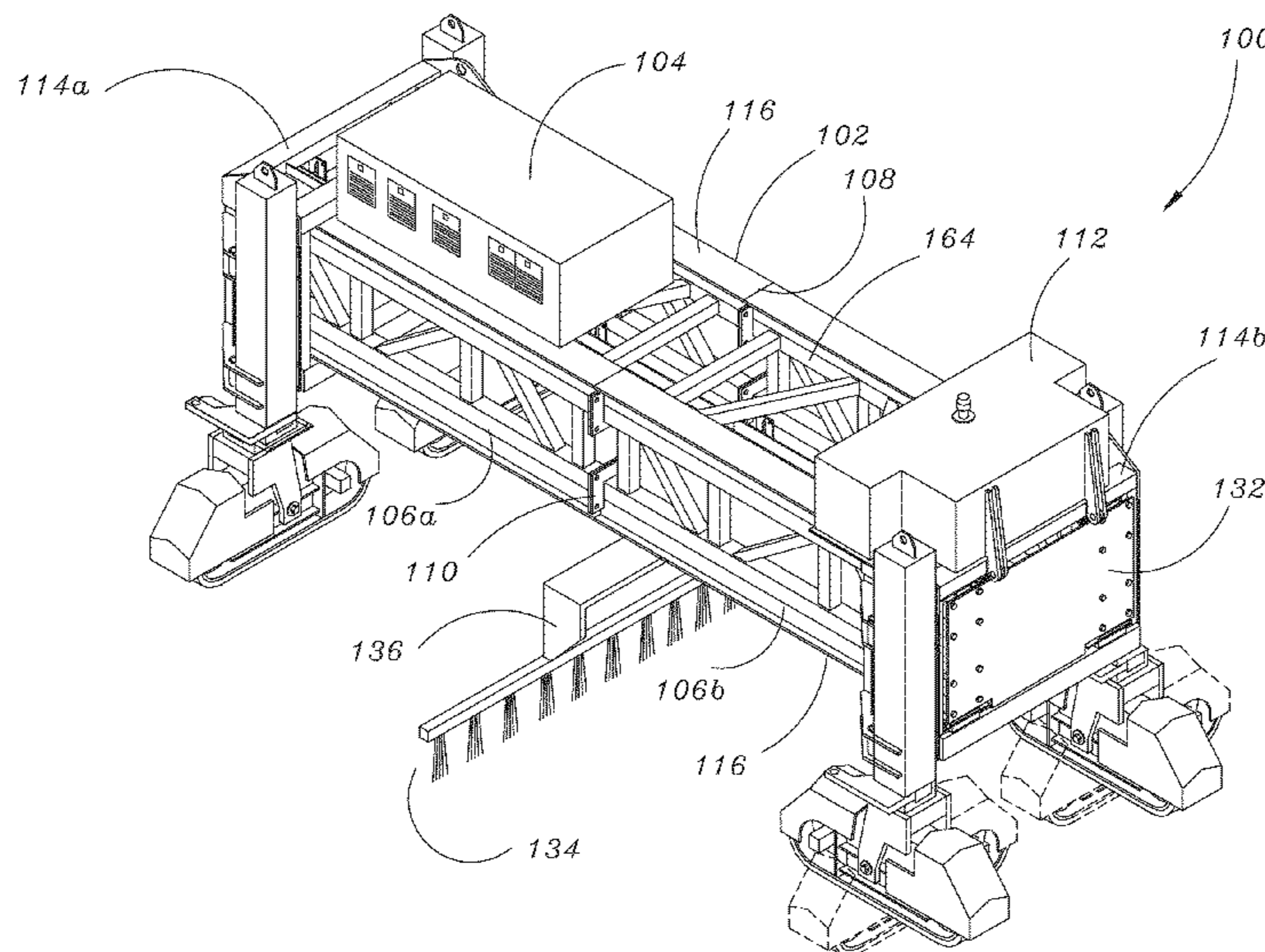
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(57) **ABSTRACT**

A modularly configurable paving operations system includes a modular framework of frame inserts, the width of the system extendible or reducible by the addition or removal of additional frame inserts. An end structure at either end of the modular framework has a front leg and a rear leg with a steerable crawler connected to each leg. Individual frame inserts may include a rail system along which end structures, accessories, or components may laterally slide. A control system can rotate one or more steerable crawlers via a steering assembly to drive, steer, or reconfigure the system. The control system may also include a tining control system, a grade control system, a spray control system, sensors and sensor arrays, and a user interface. The system may accommodate one or more accessories through an undercarriage mounted to the modular framework, which may further include a hydraulic height adjuster.

**18 Claims, 36 Drawing Sheets**



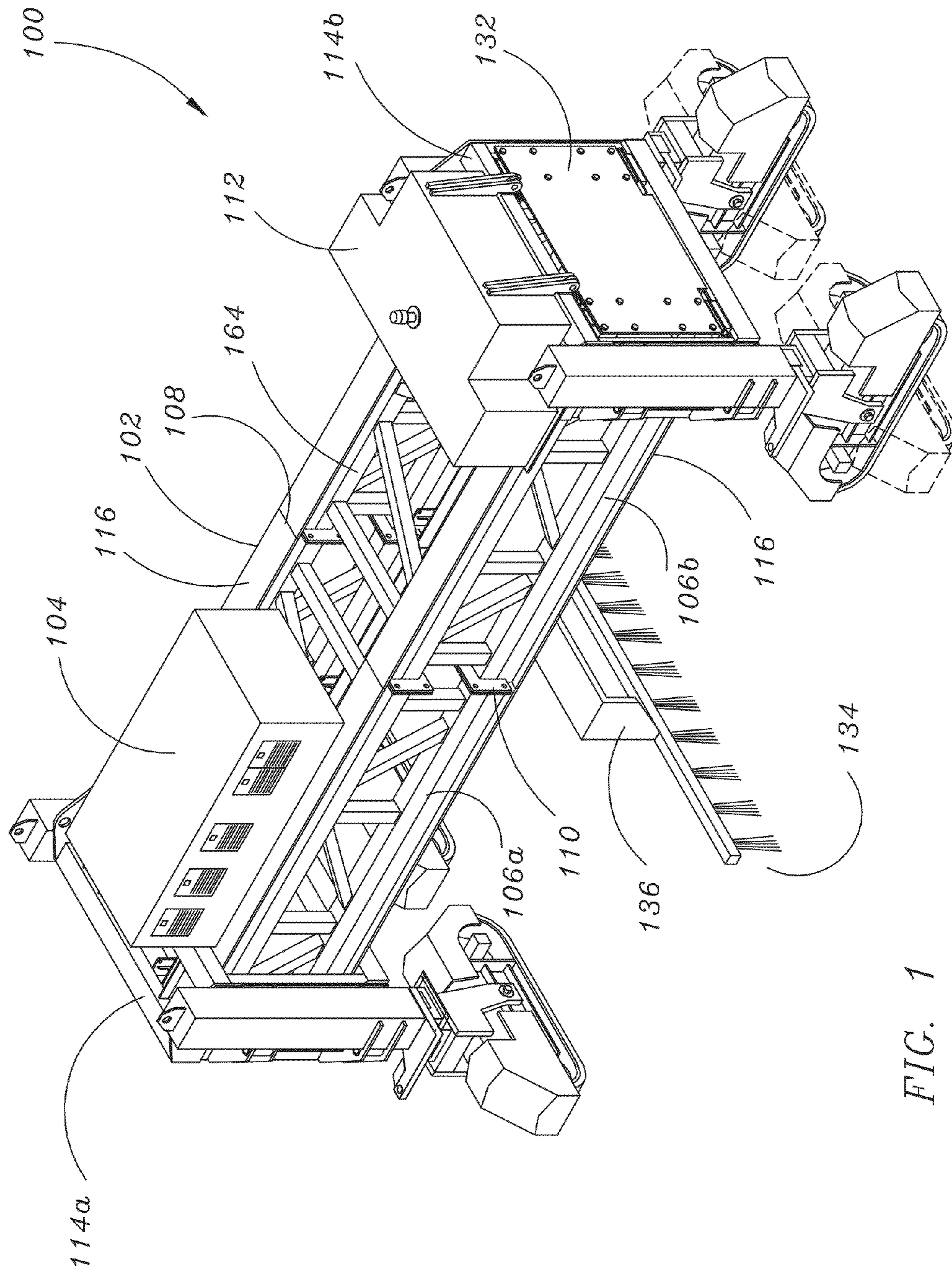


FIG. 1



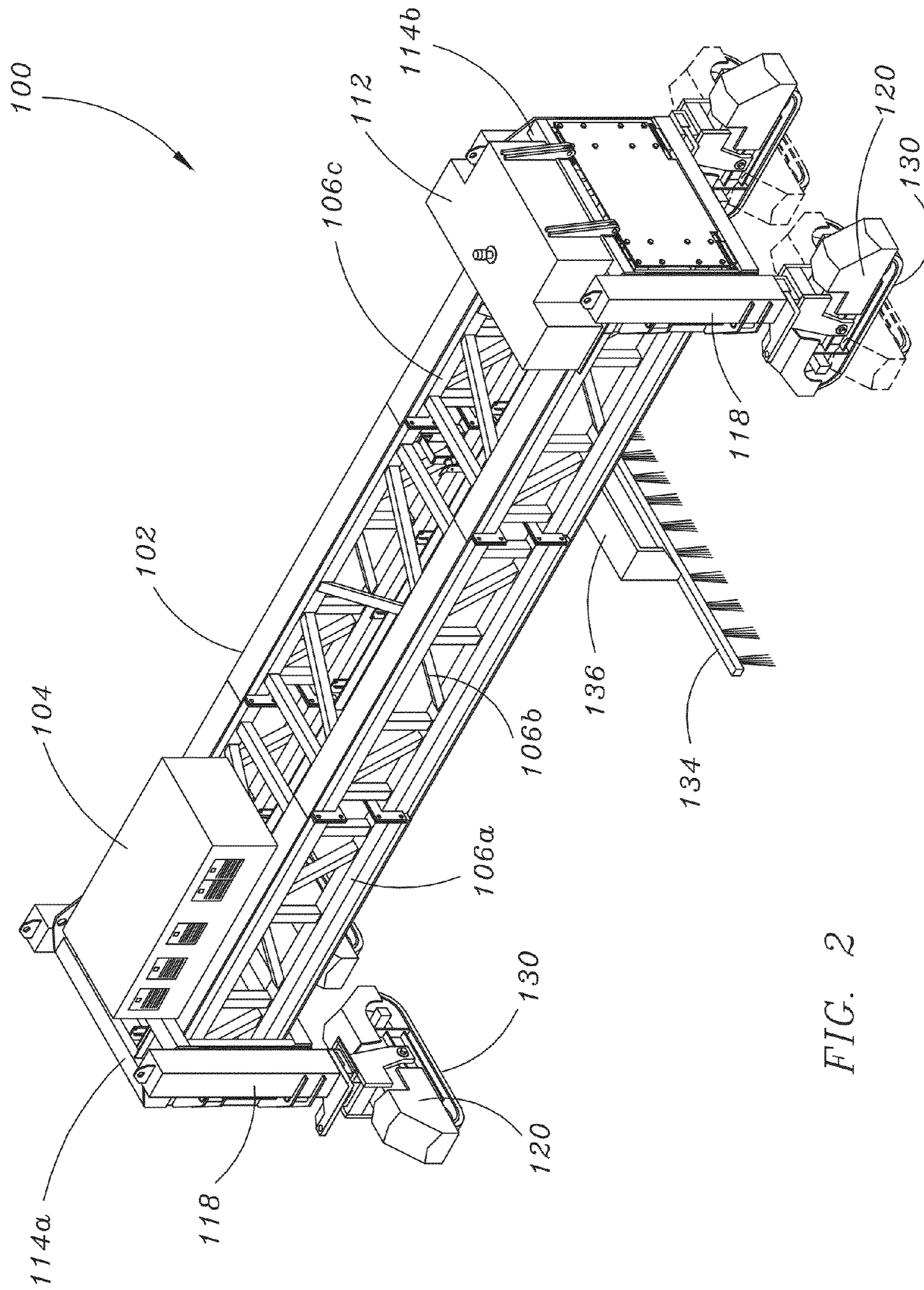


FIG. 2

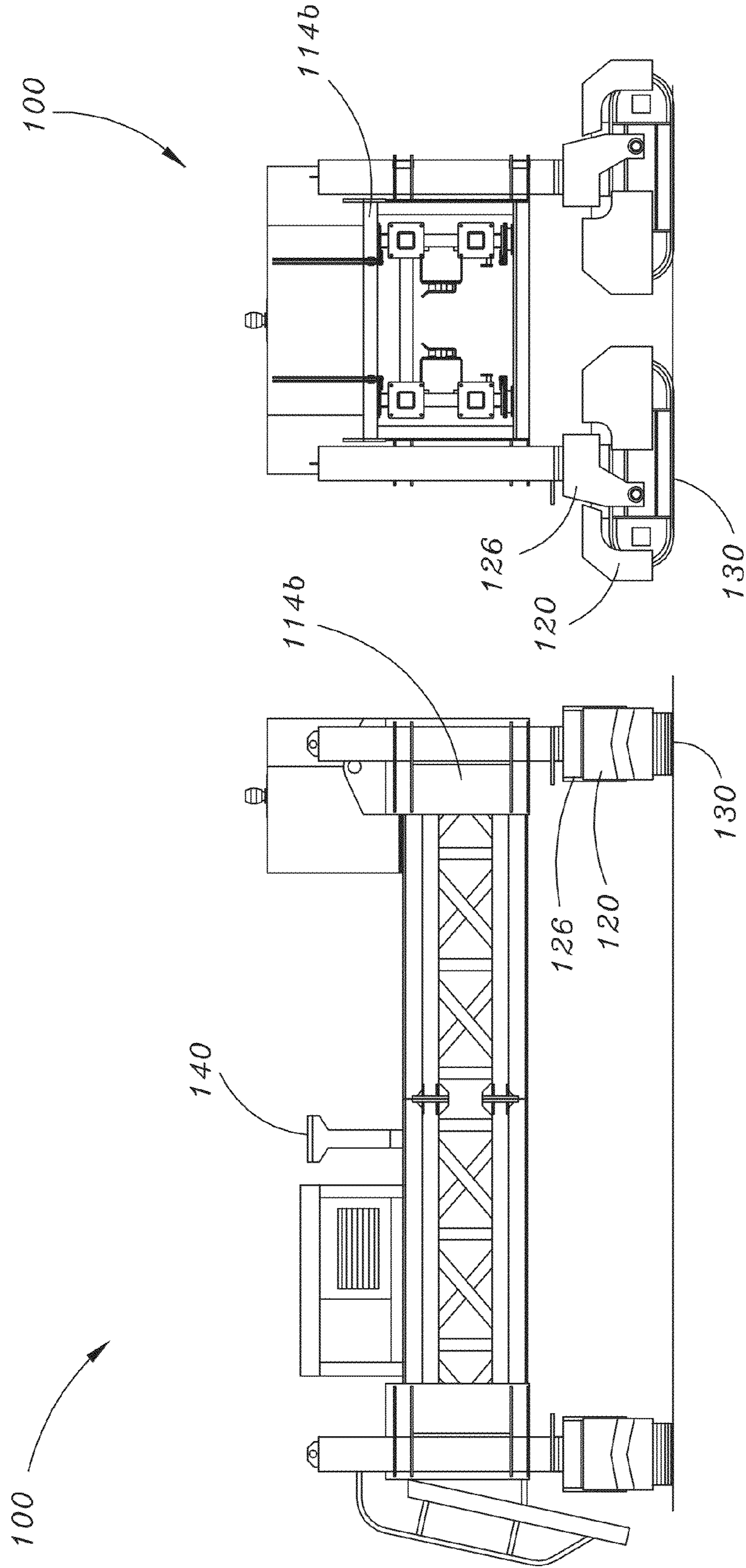


FIG. 3A

FIG. 3B

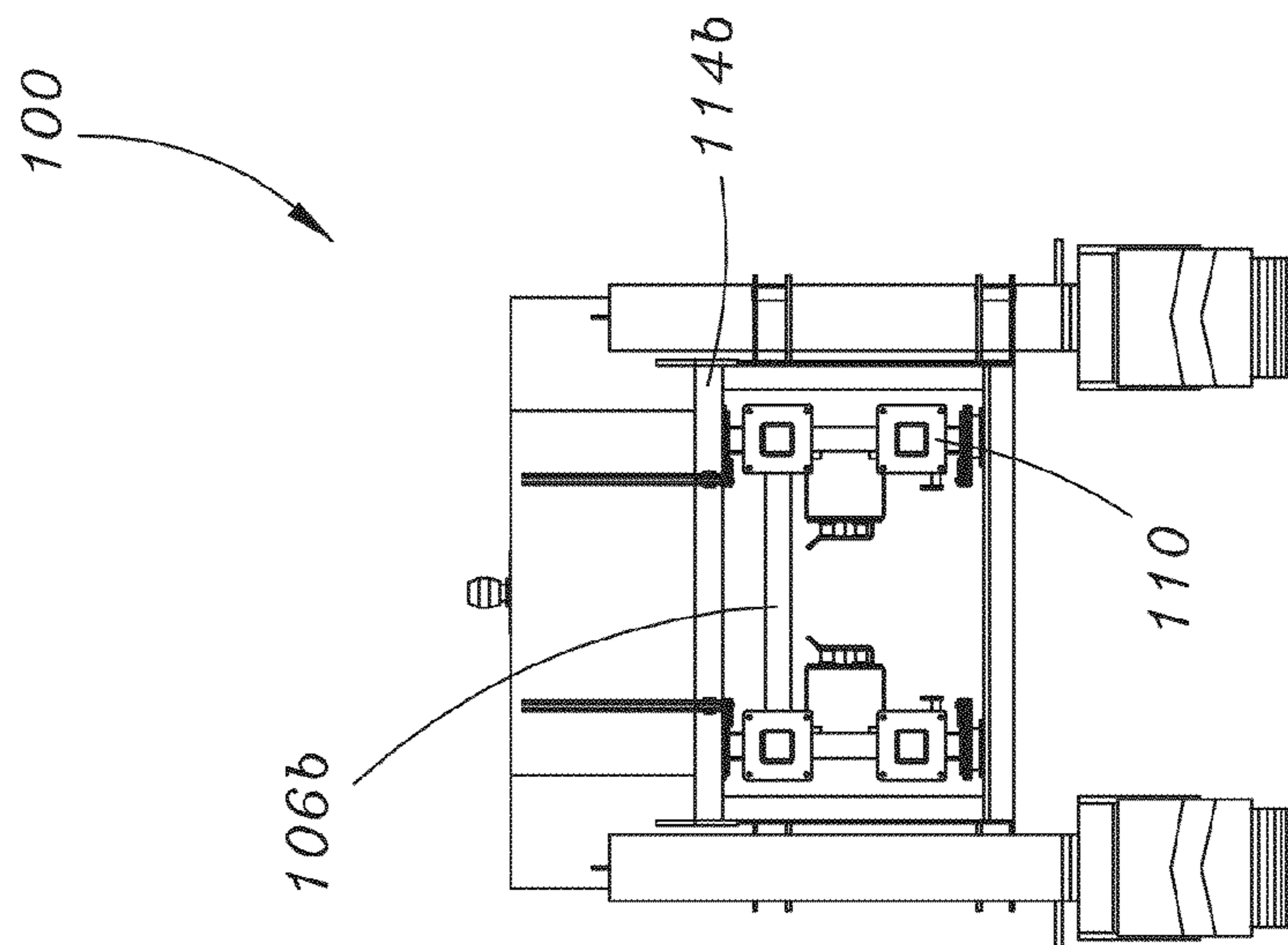


FIG. 4B

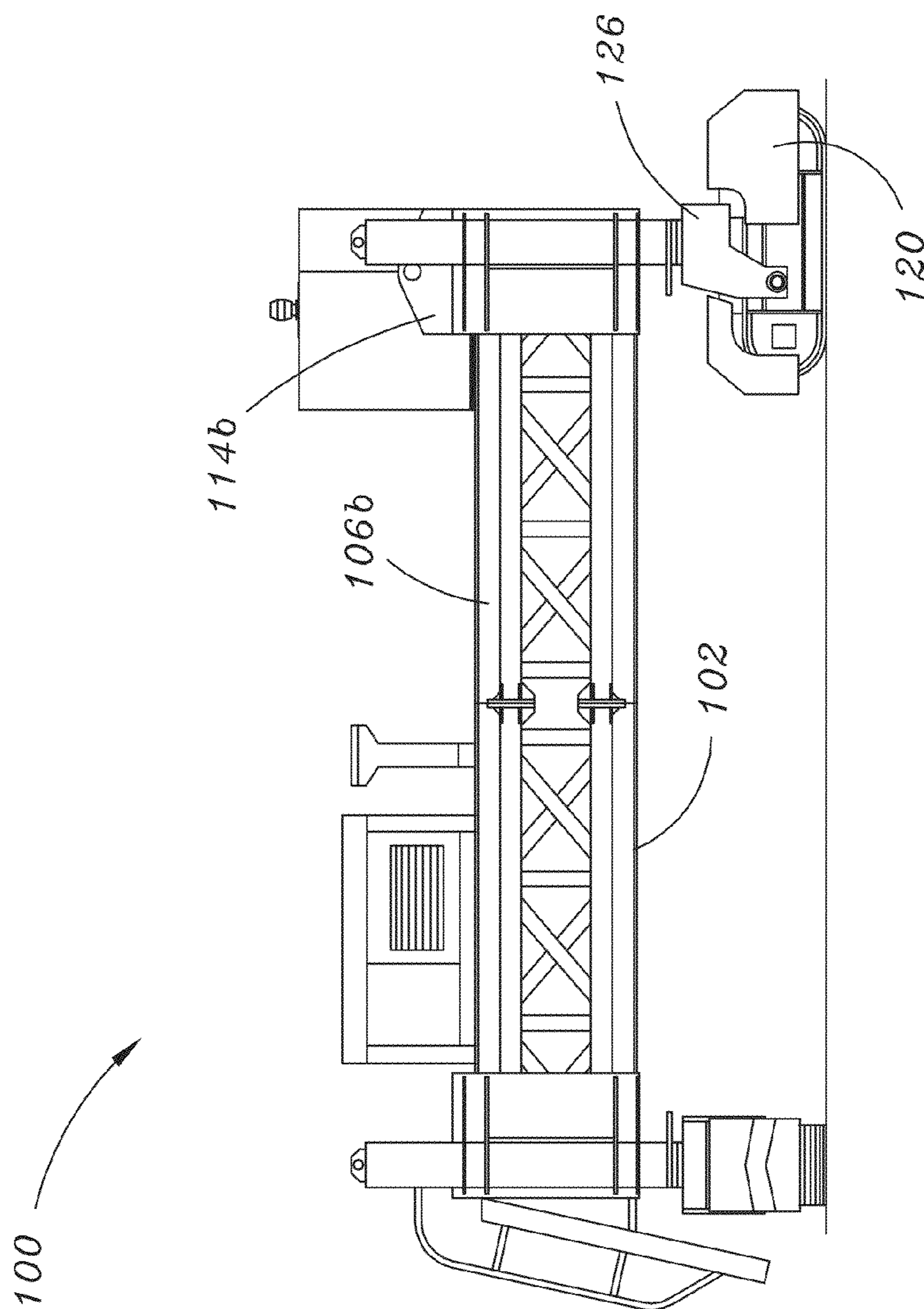


FIG. 4A



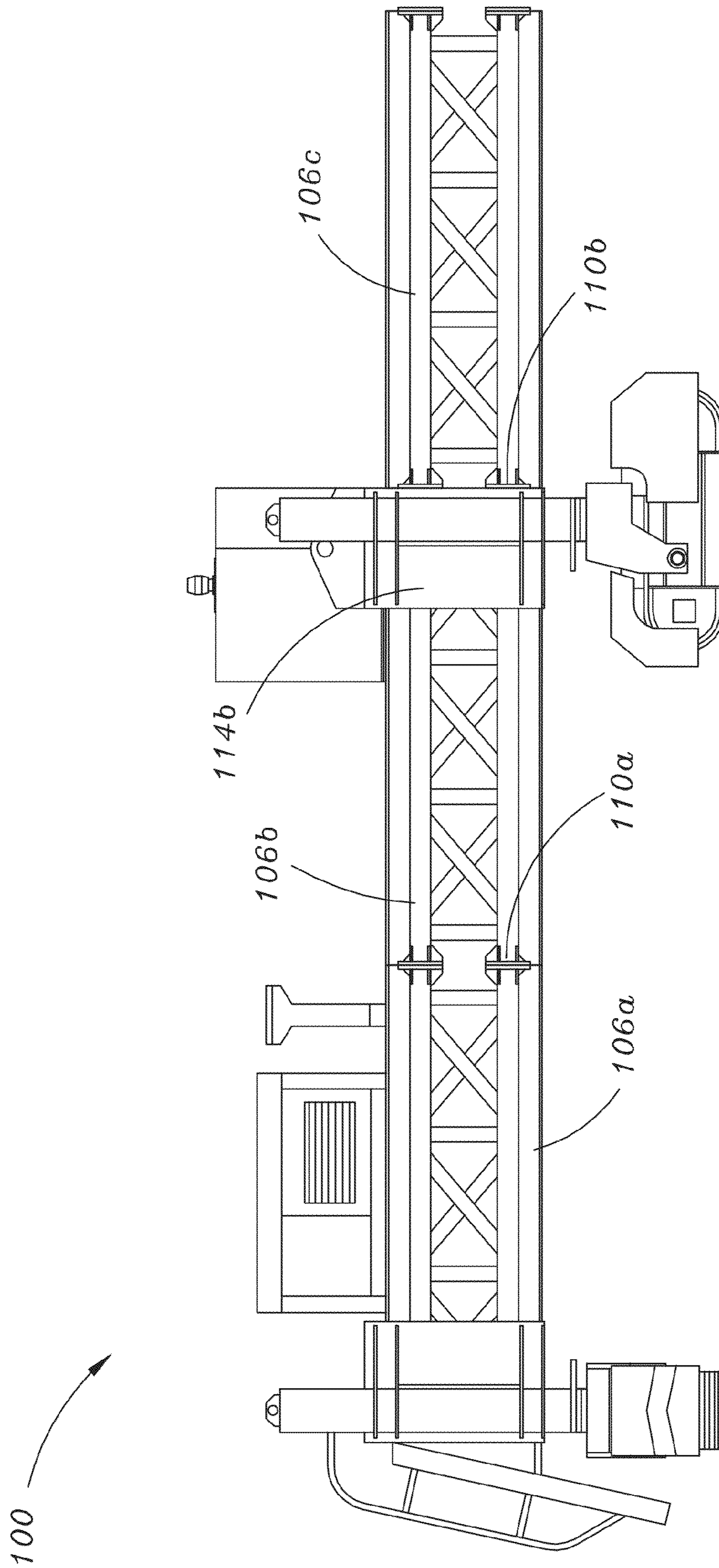


FIG. 5A

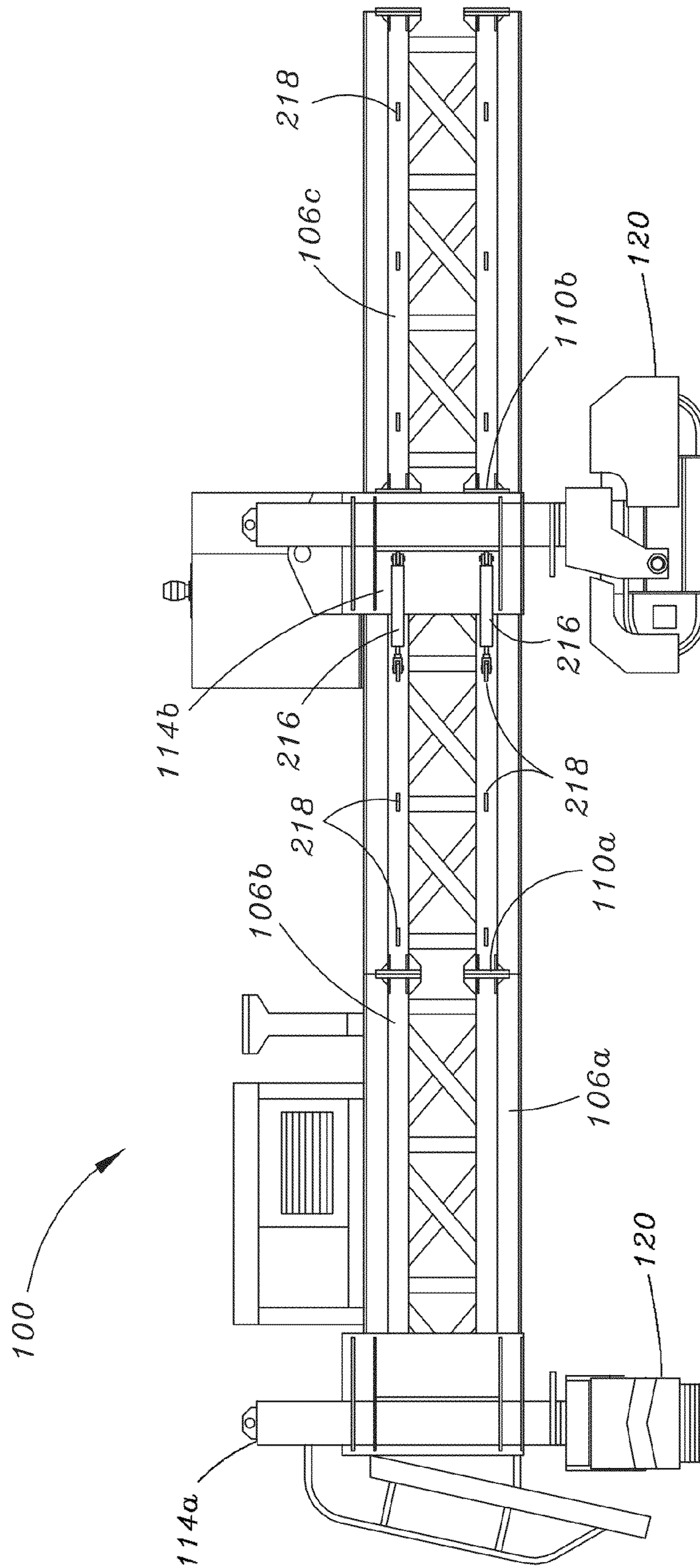


FIG. 5B

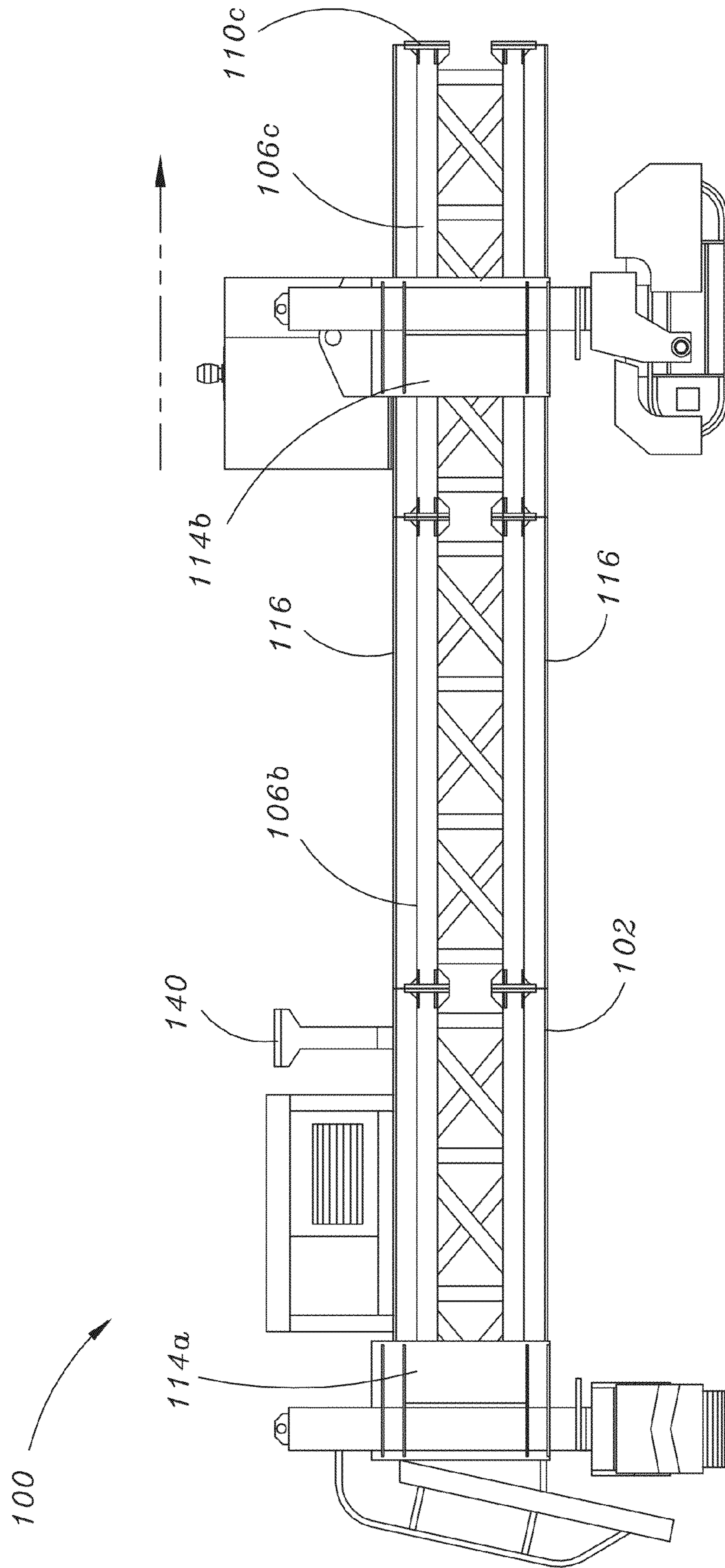


FIG. 6



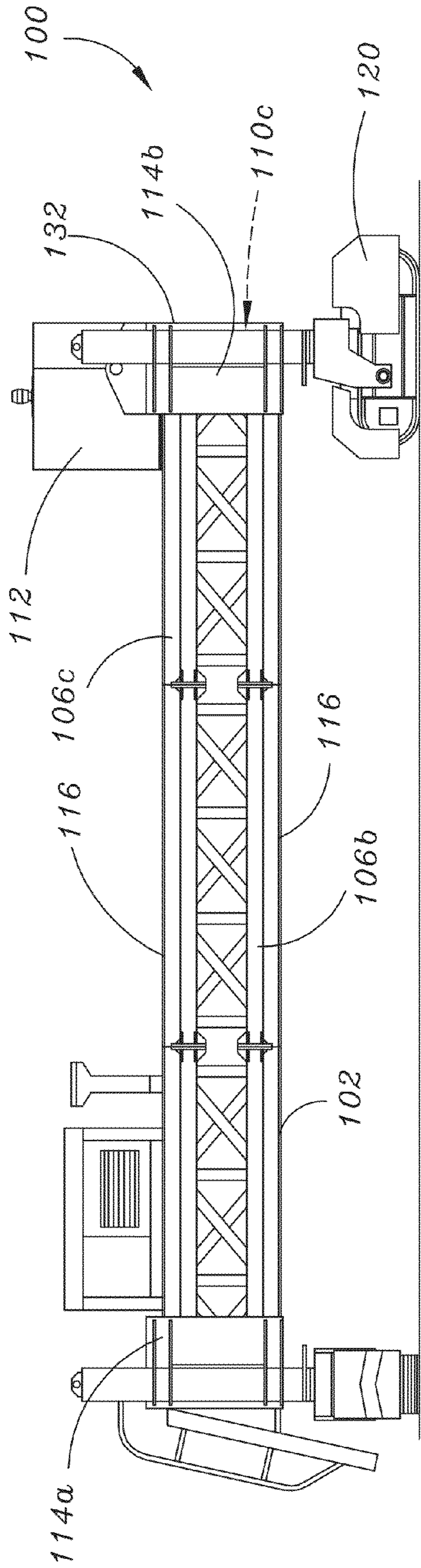


FIG. 7A

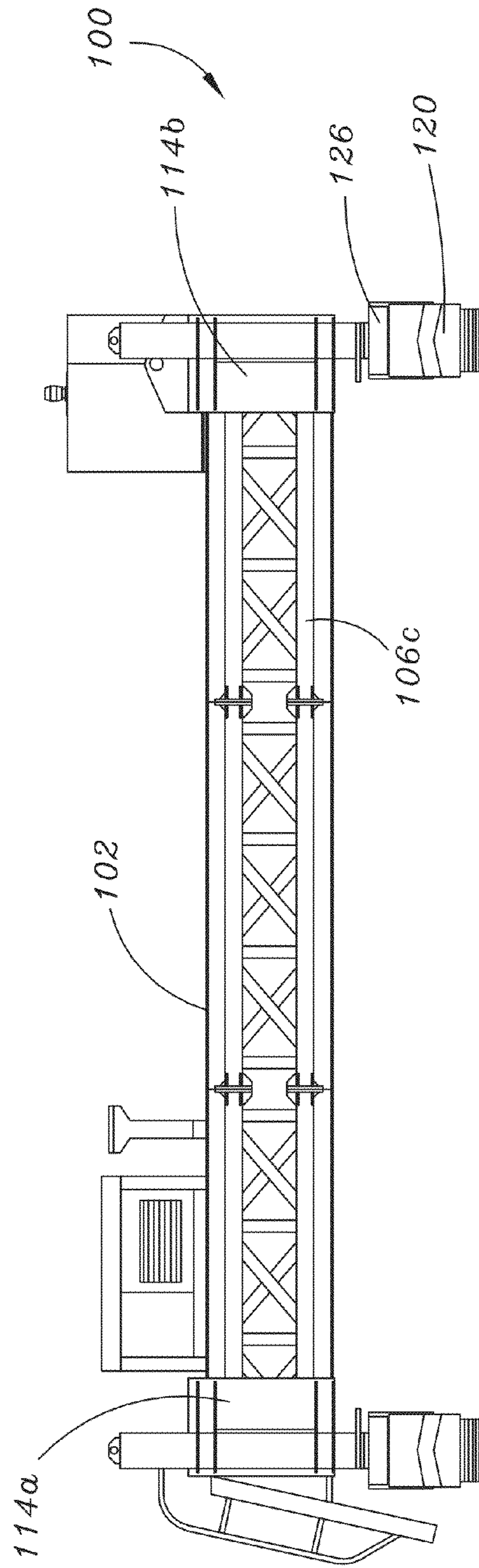


FIG. 7B

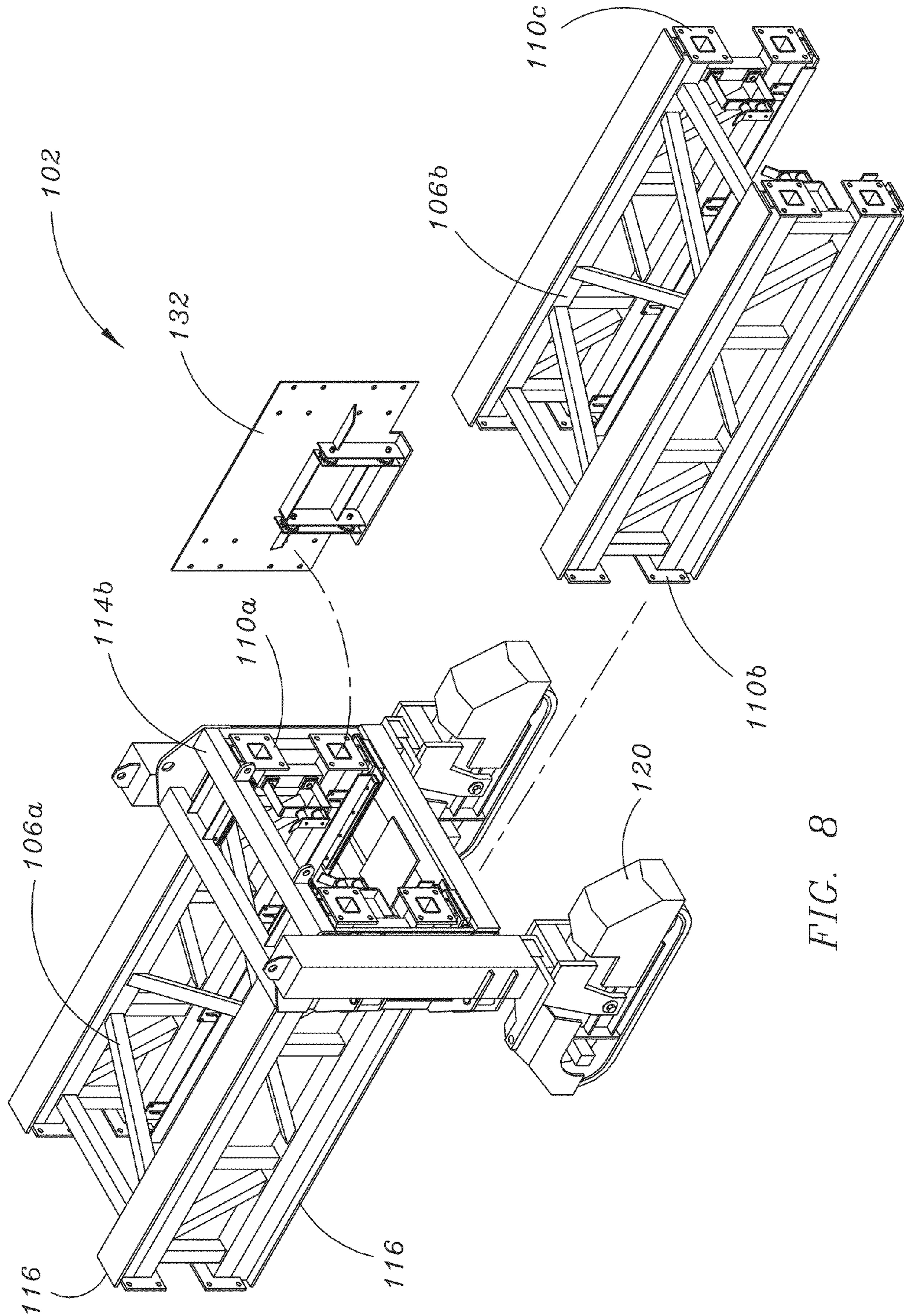


FIG. 8



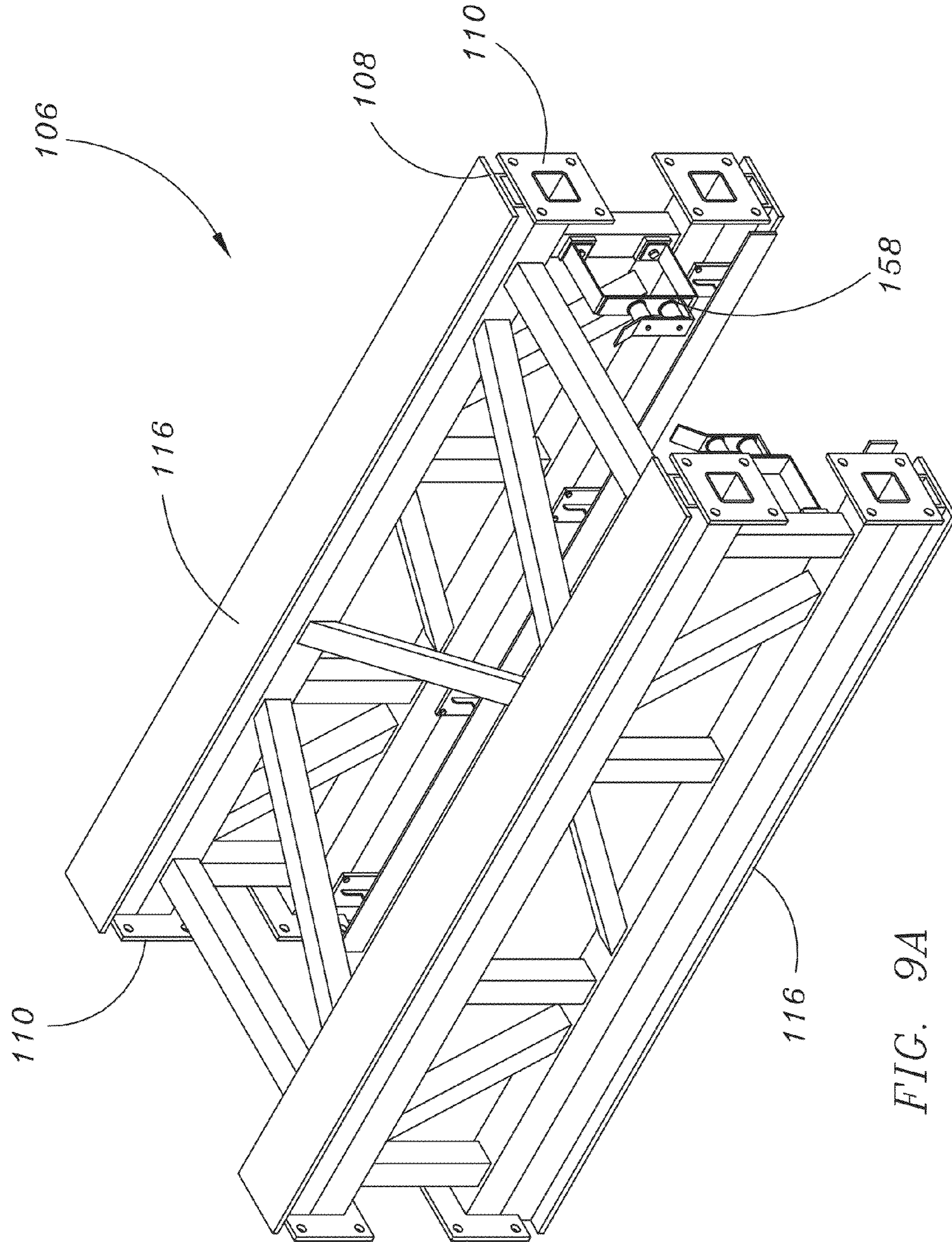


FIG. 9A



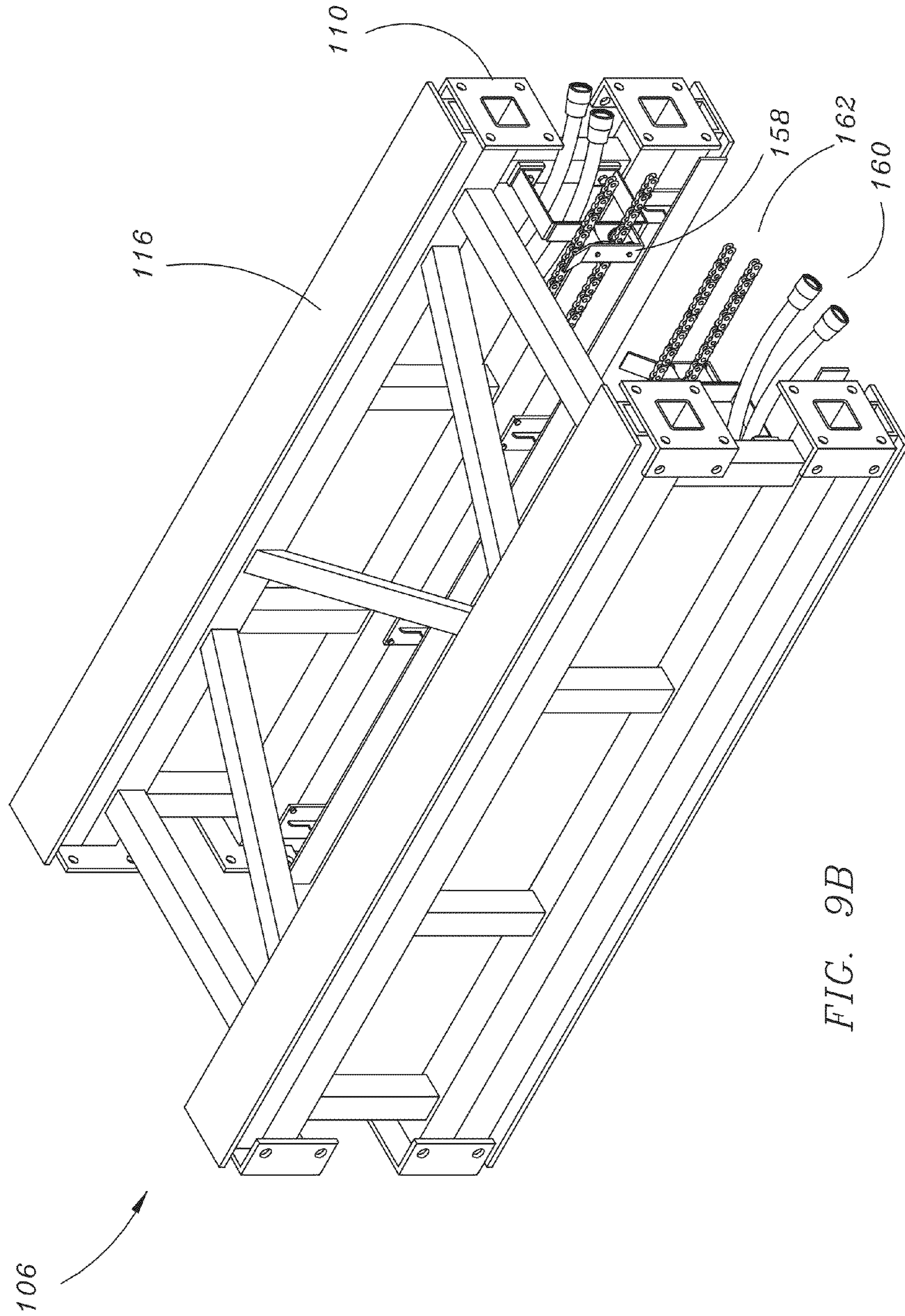


FIG. 9B

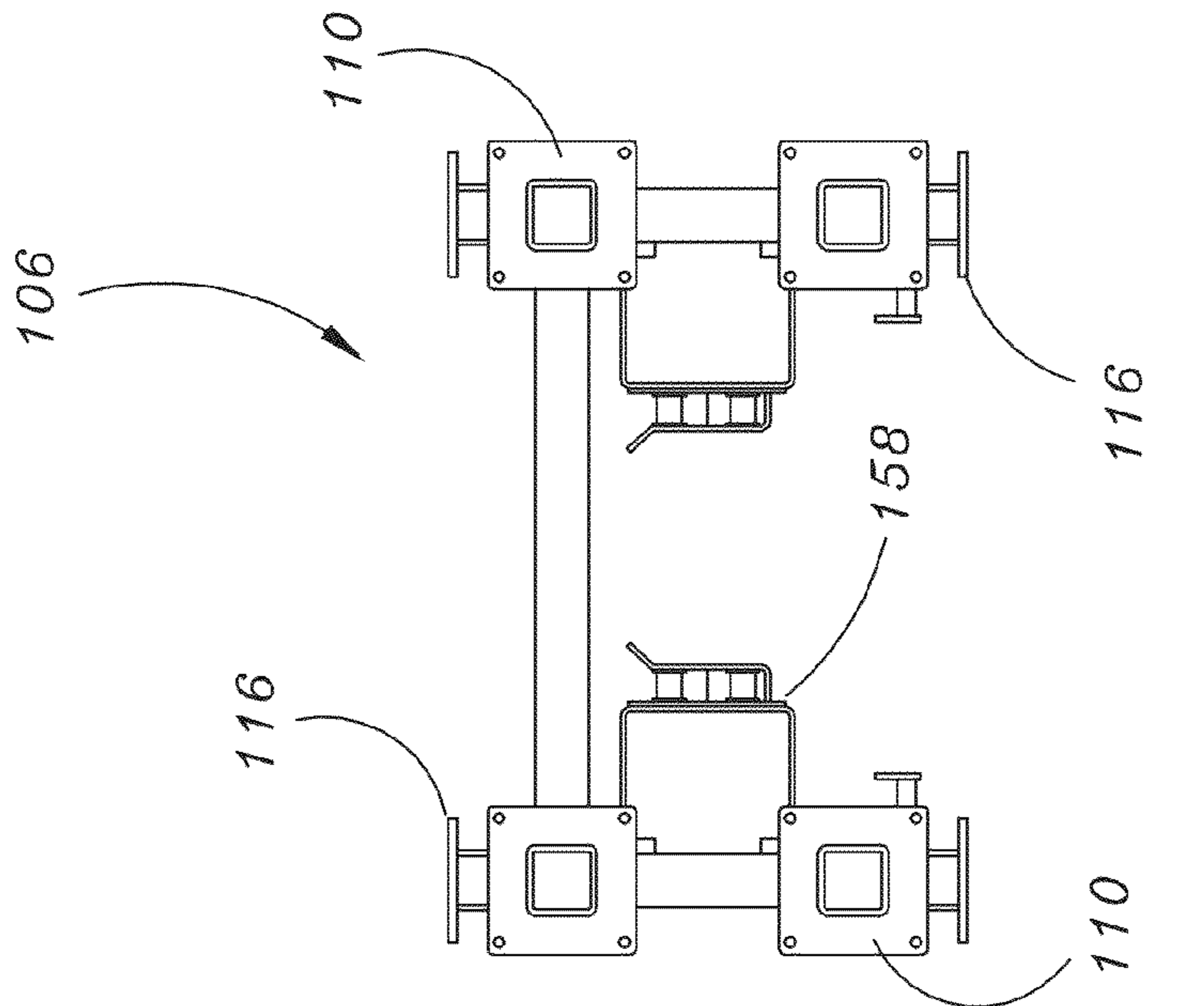


FIG. 10A

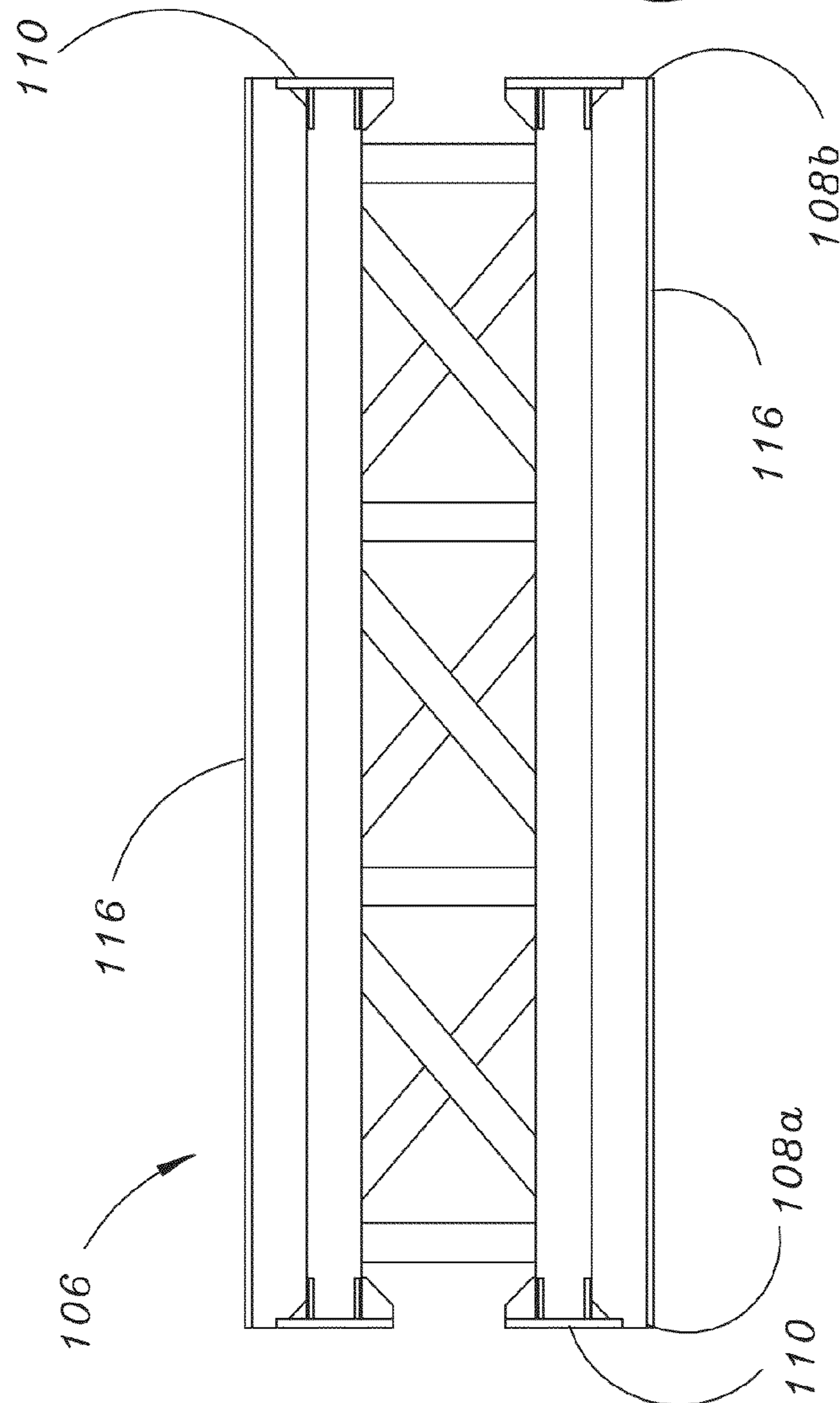


FIG. 10B

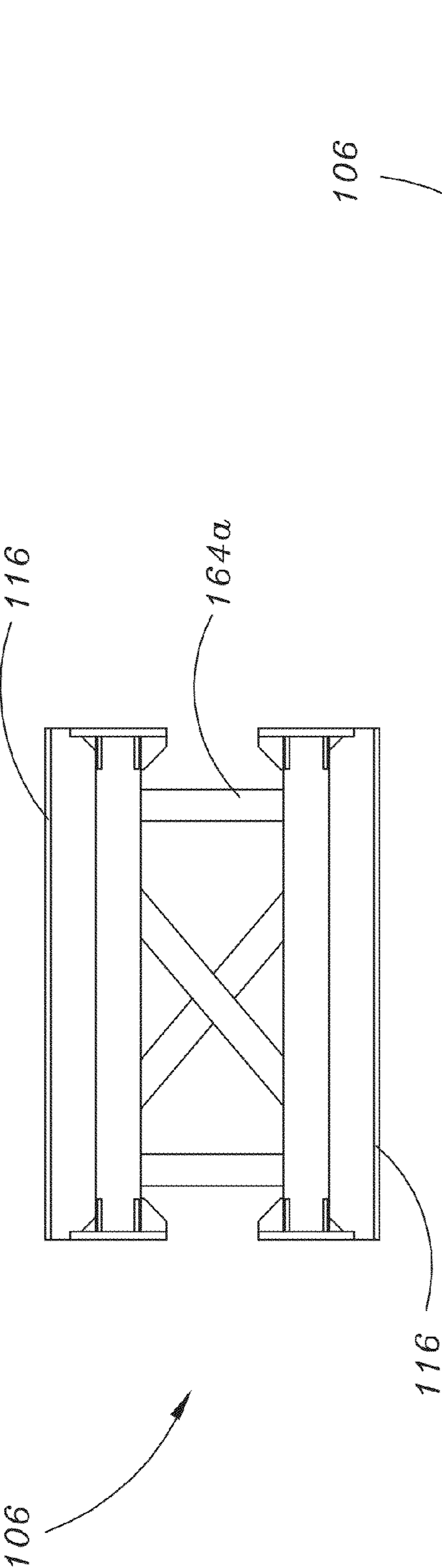


FIG. 11A

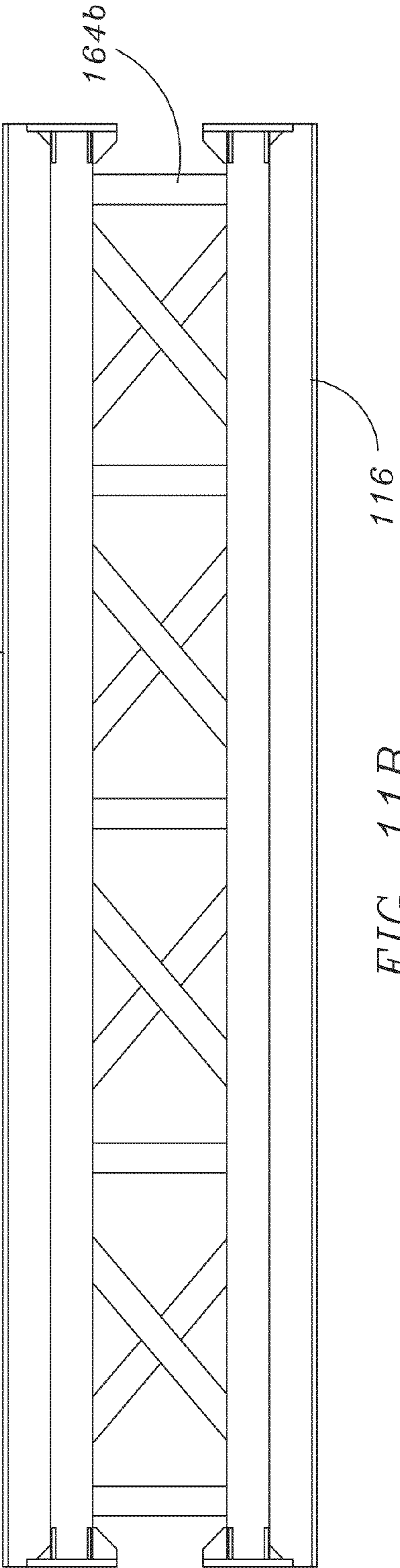


FIG. 11B



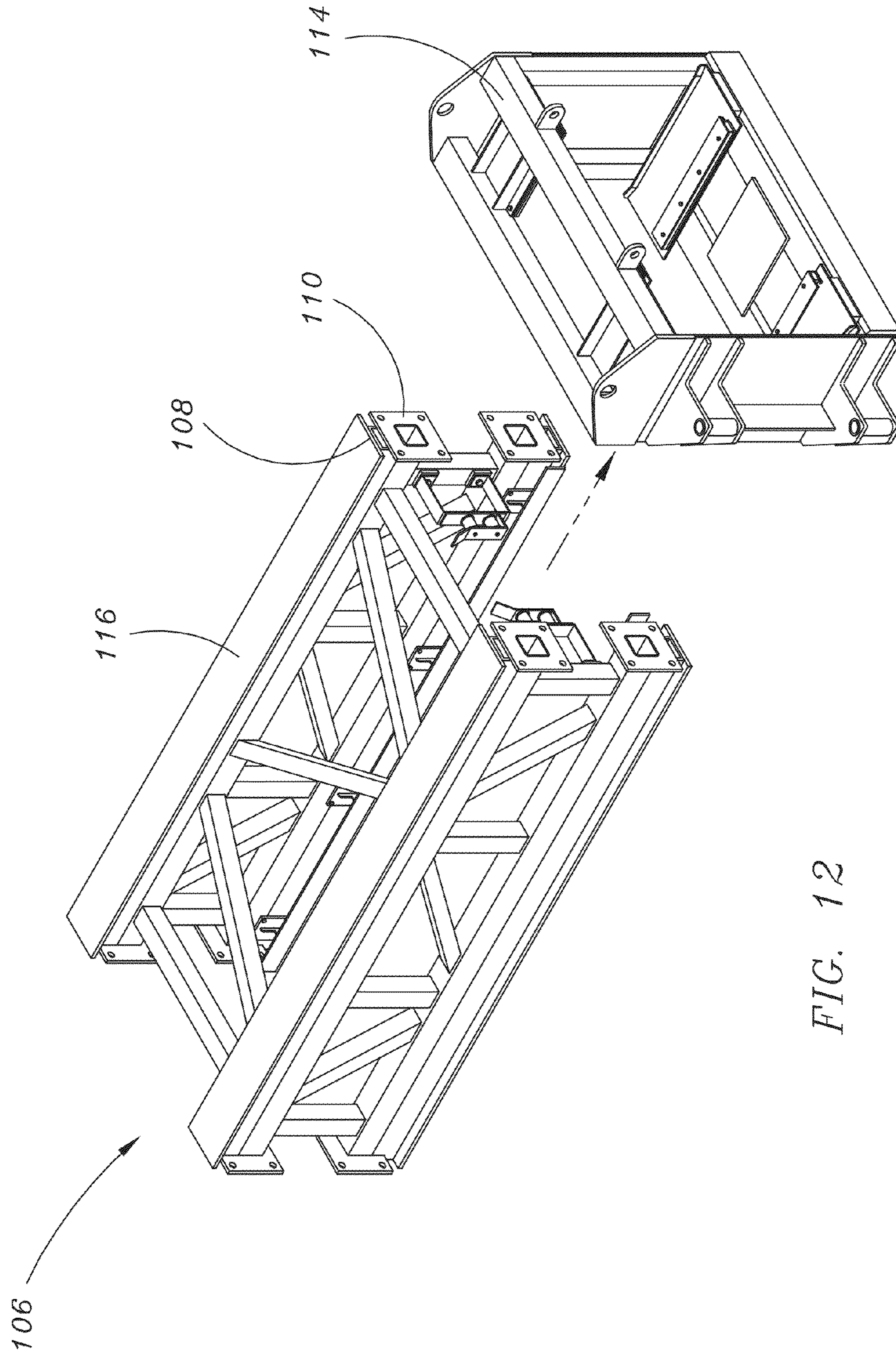


FIG. 12

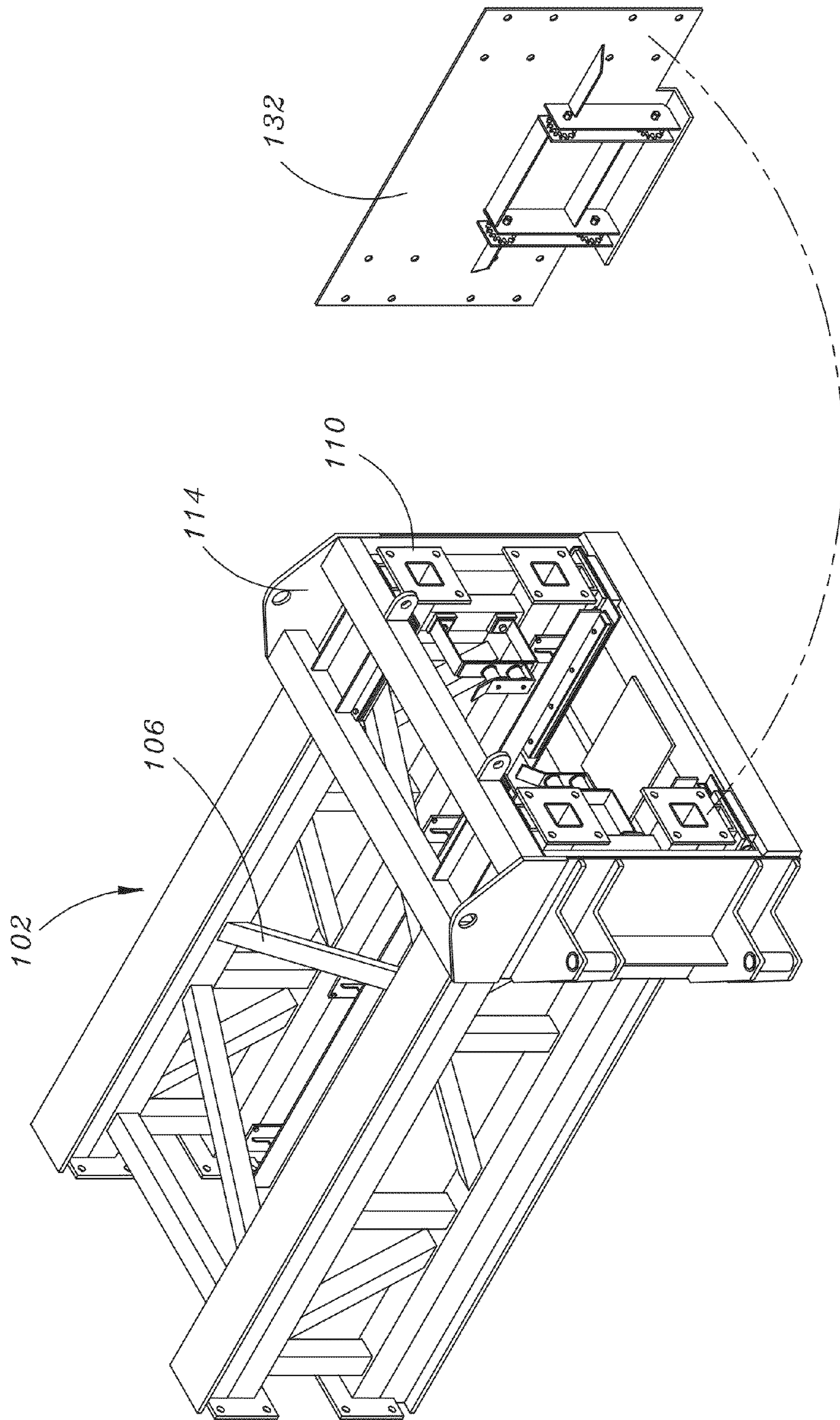


FIG. 13

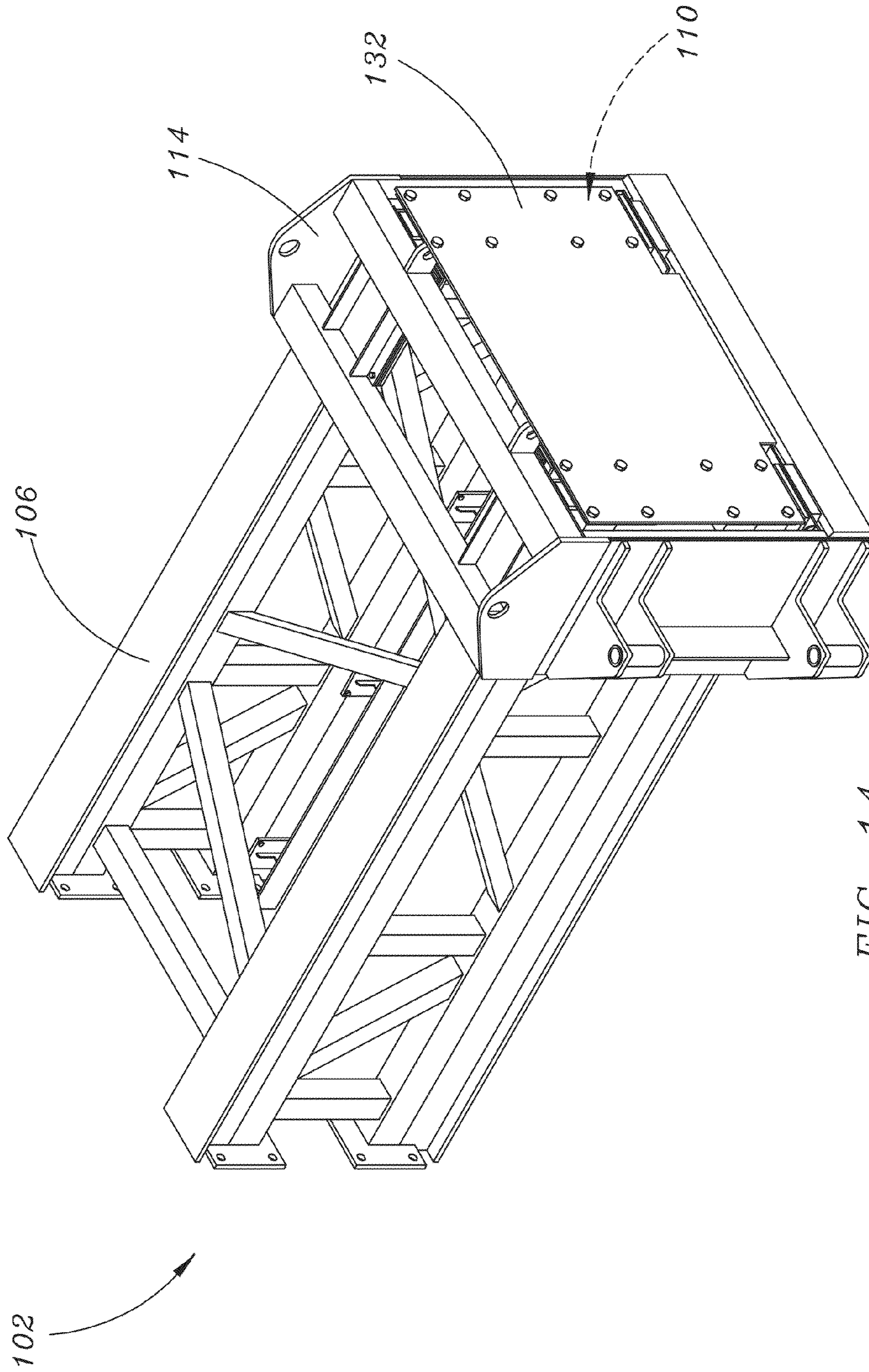


FIG. 14



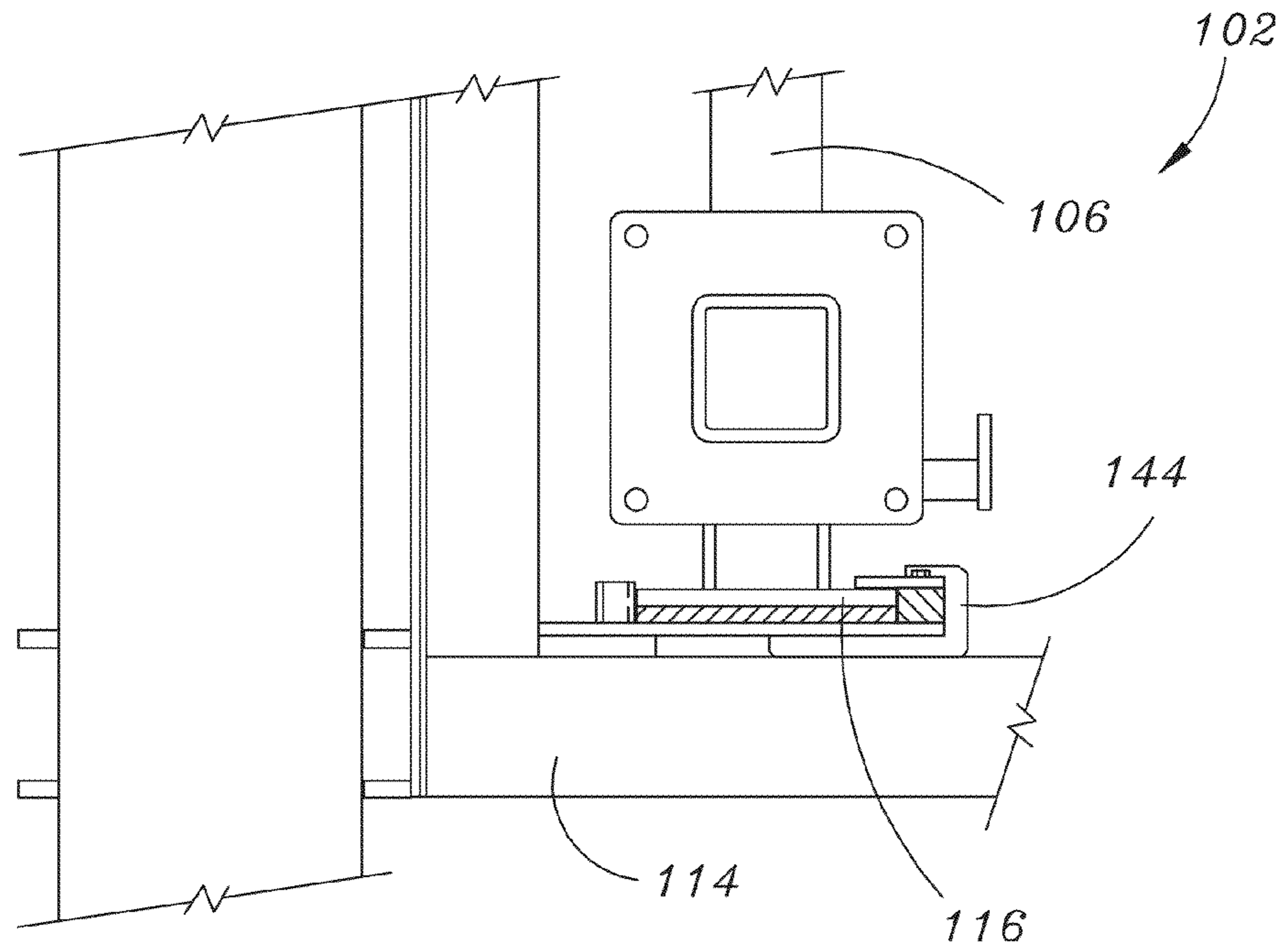


FIG. 15

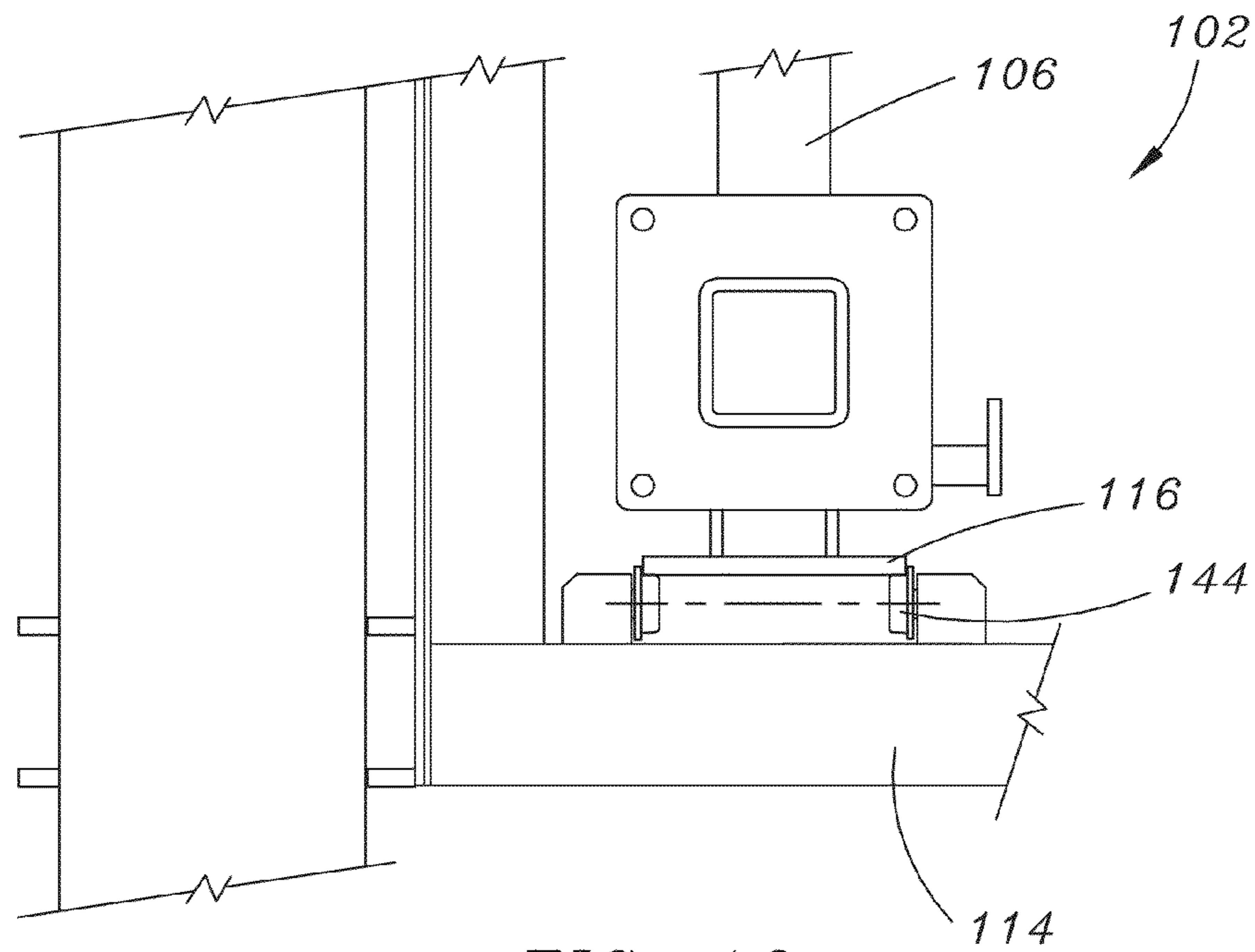


FIG. 16

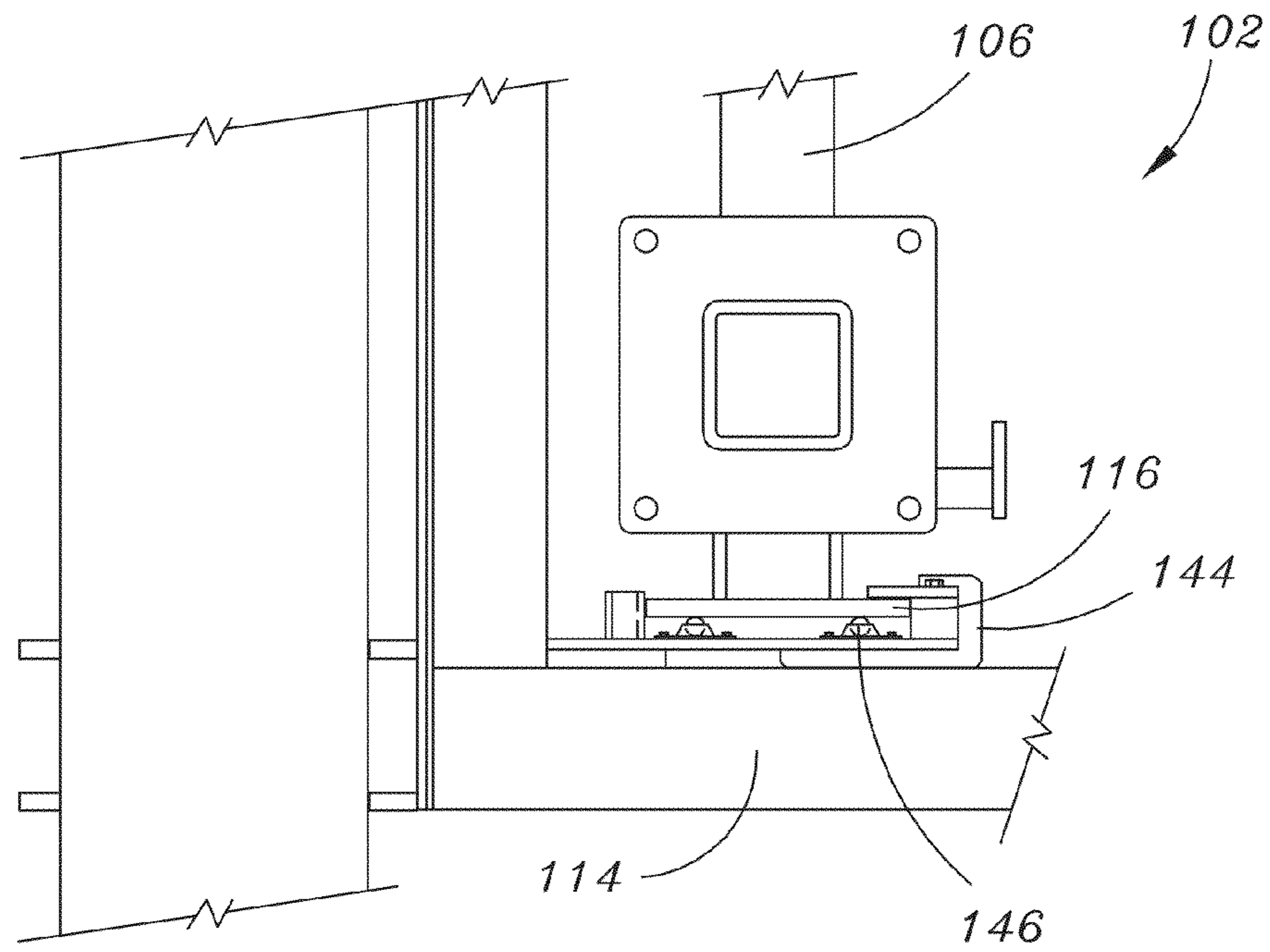


FIG. 17

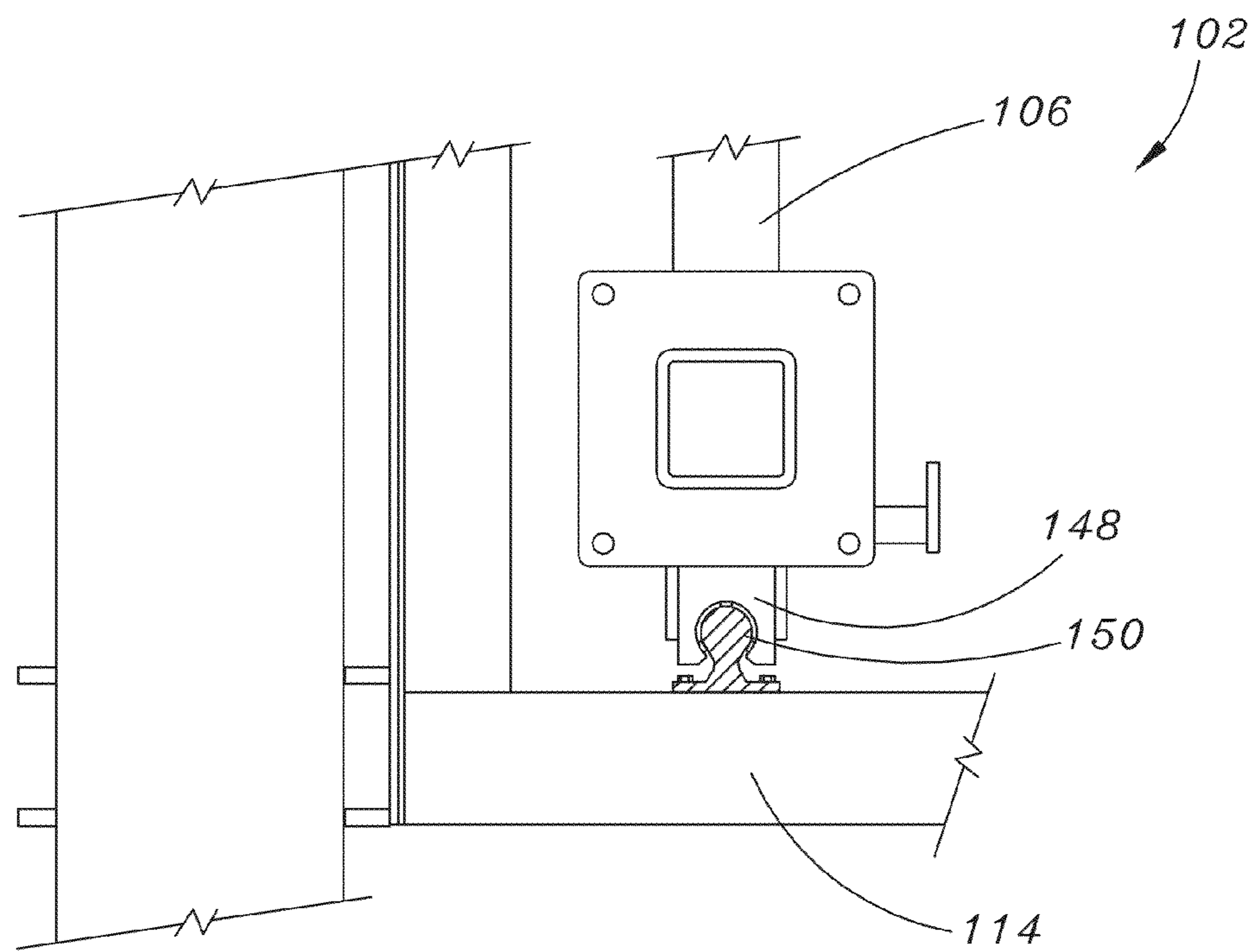


FIG. 18

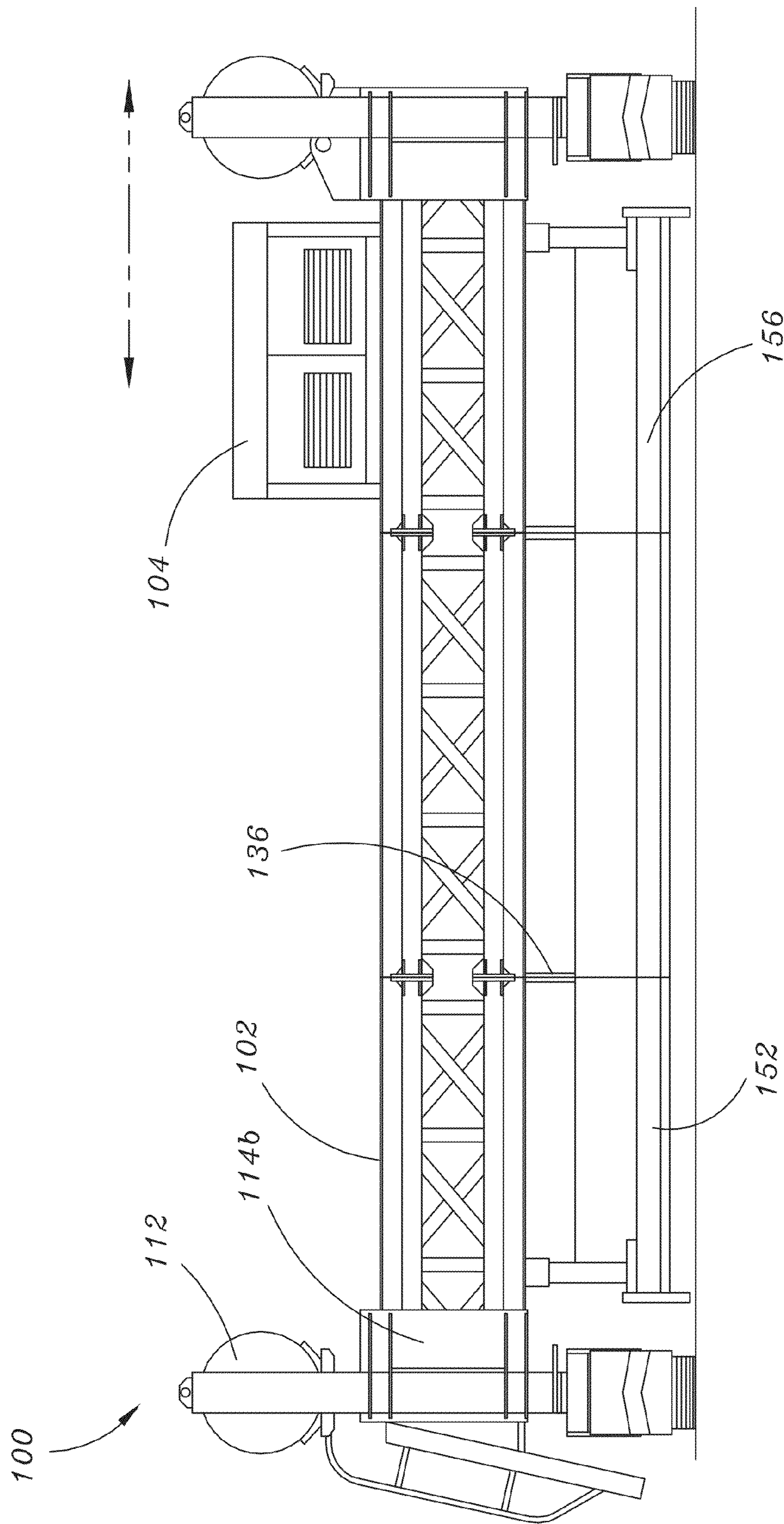


FIG. 19



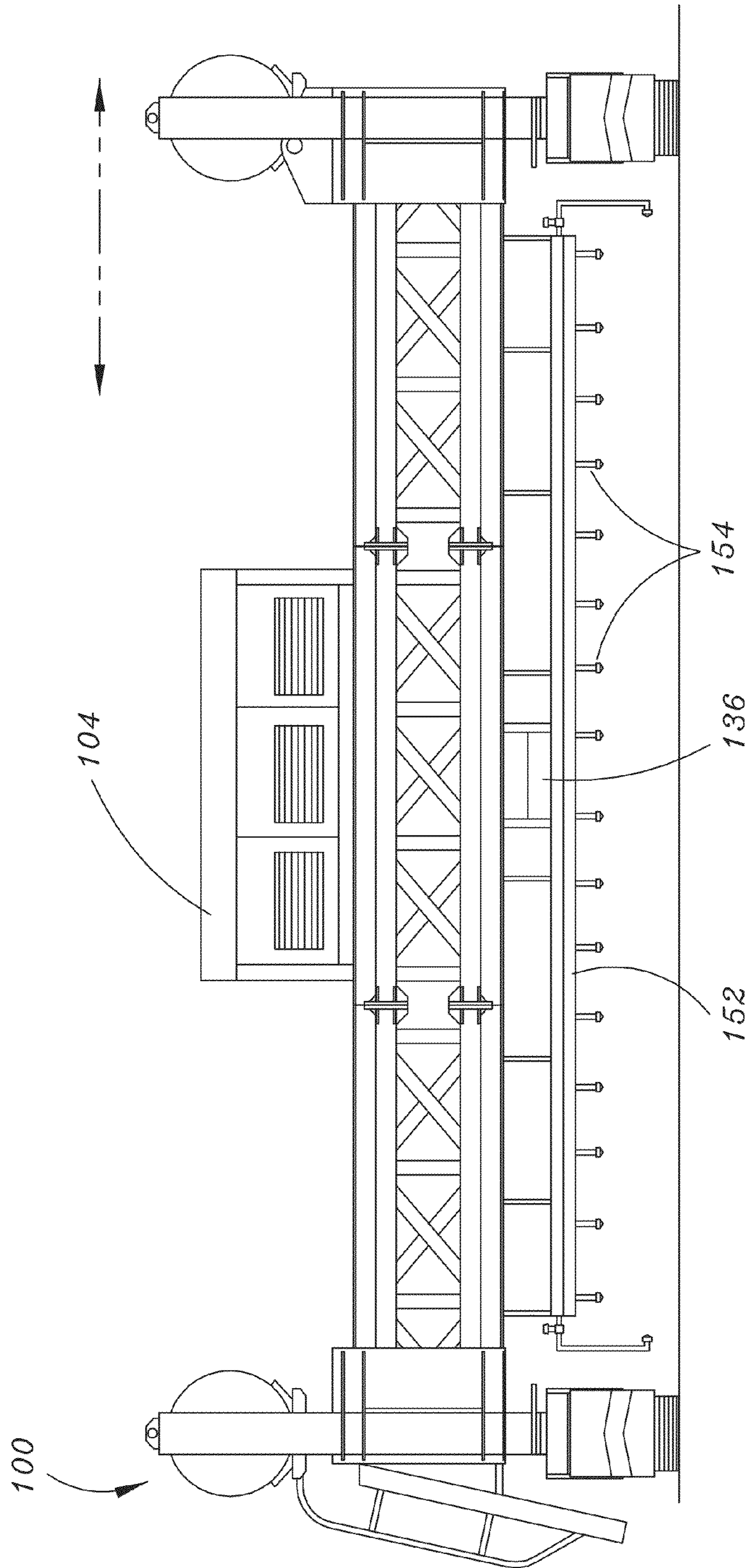


FIG. 20

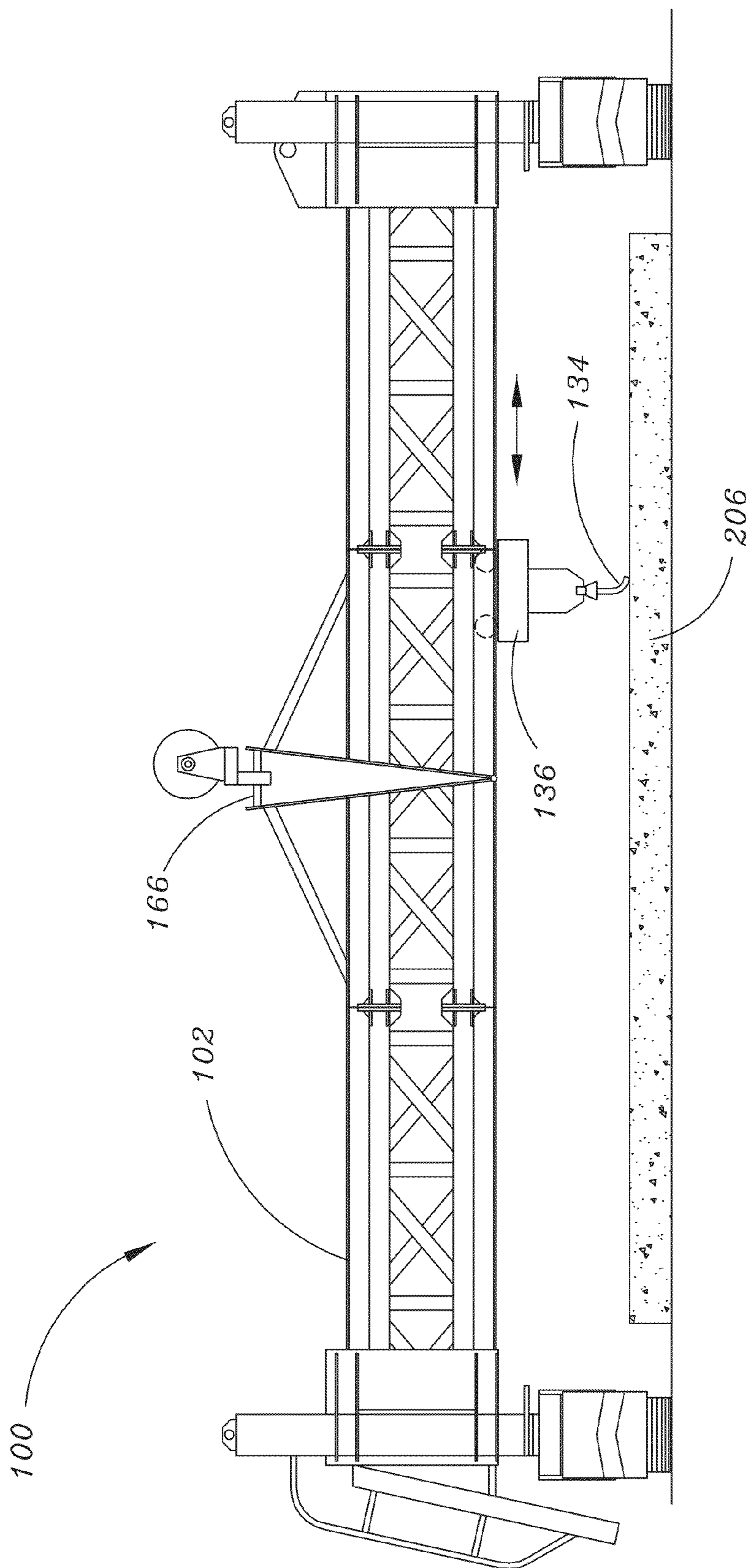


FIG. 21A

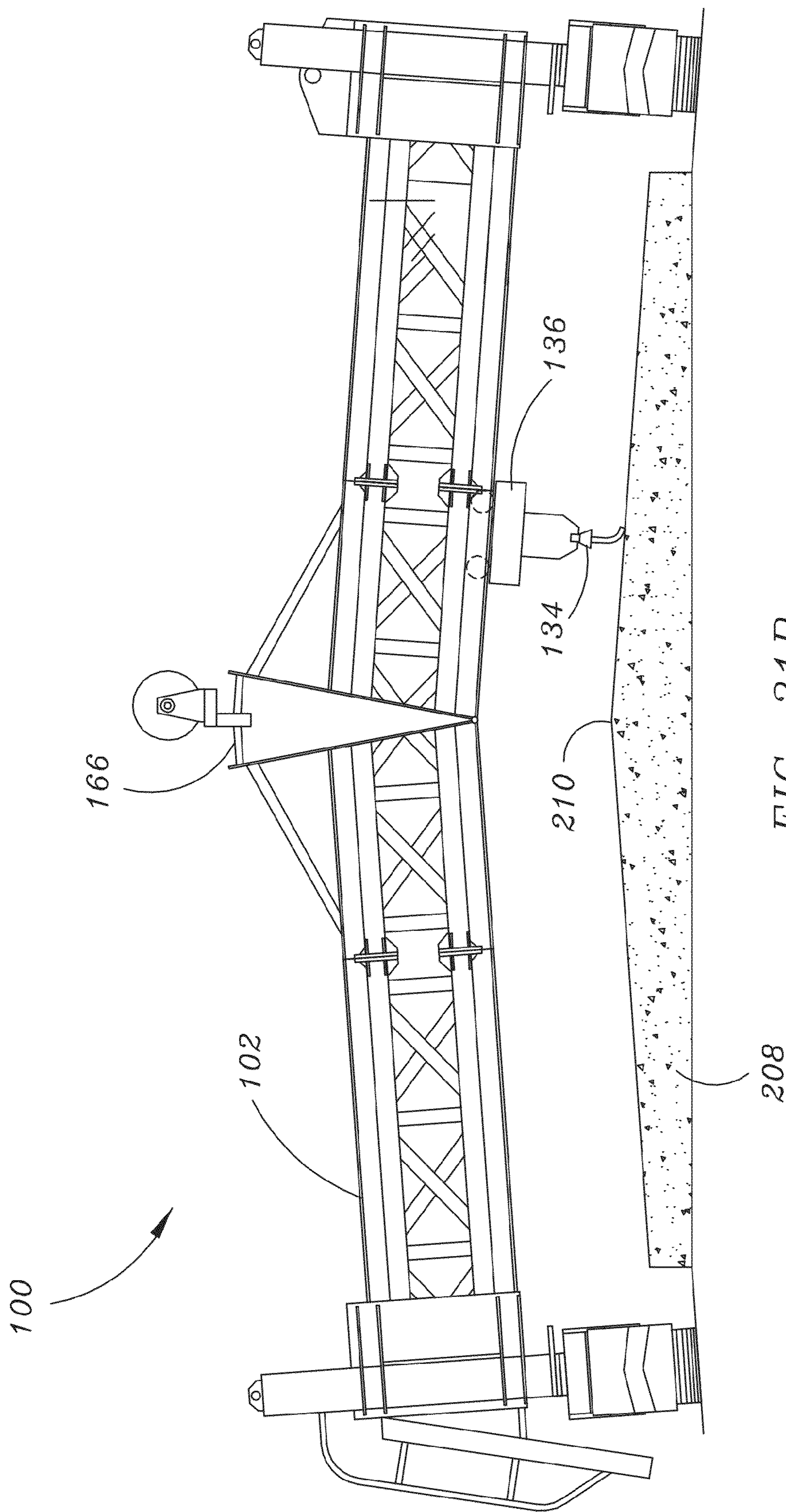


FIG. 21B



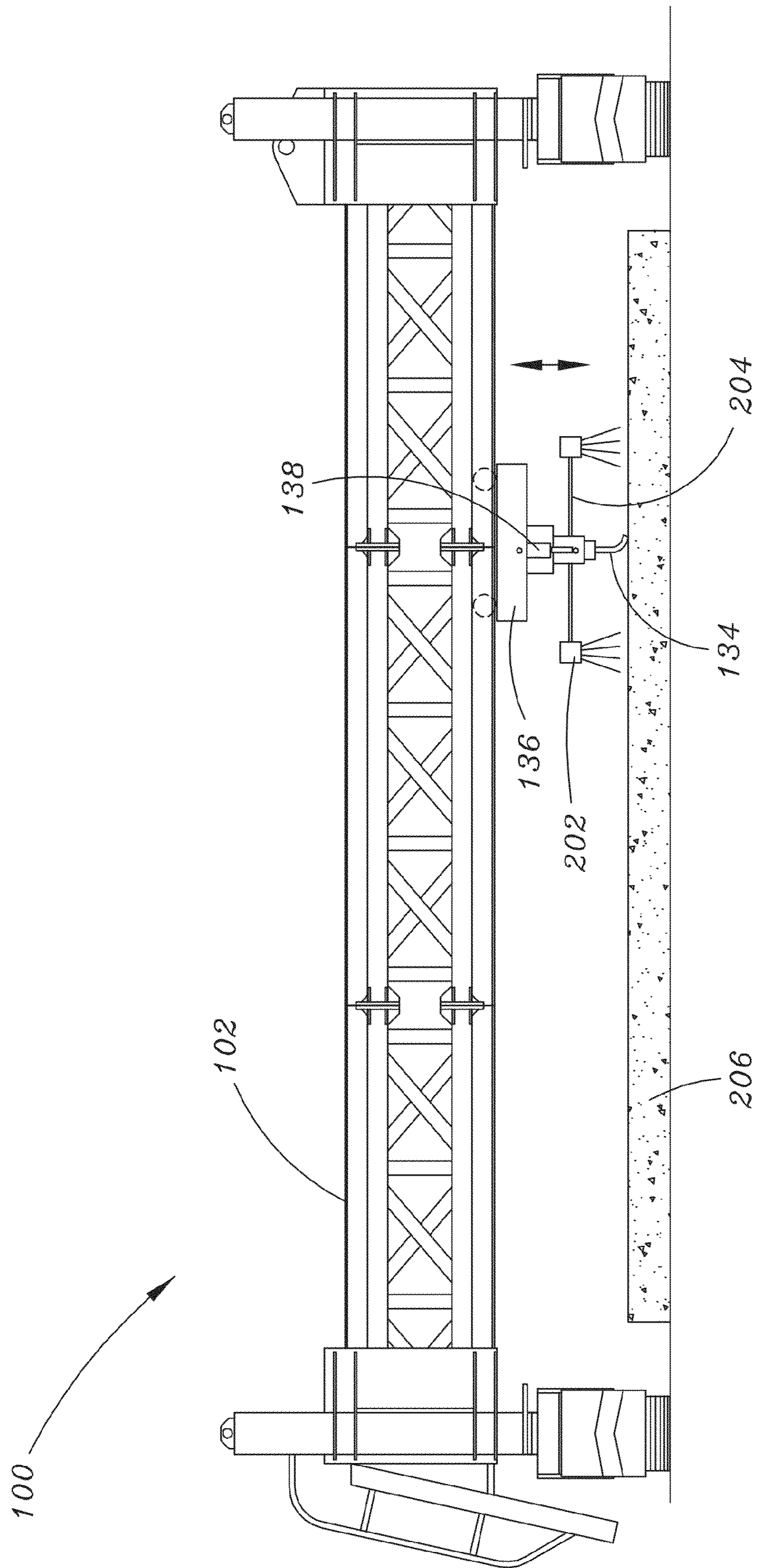


FIG. 21C

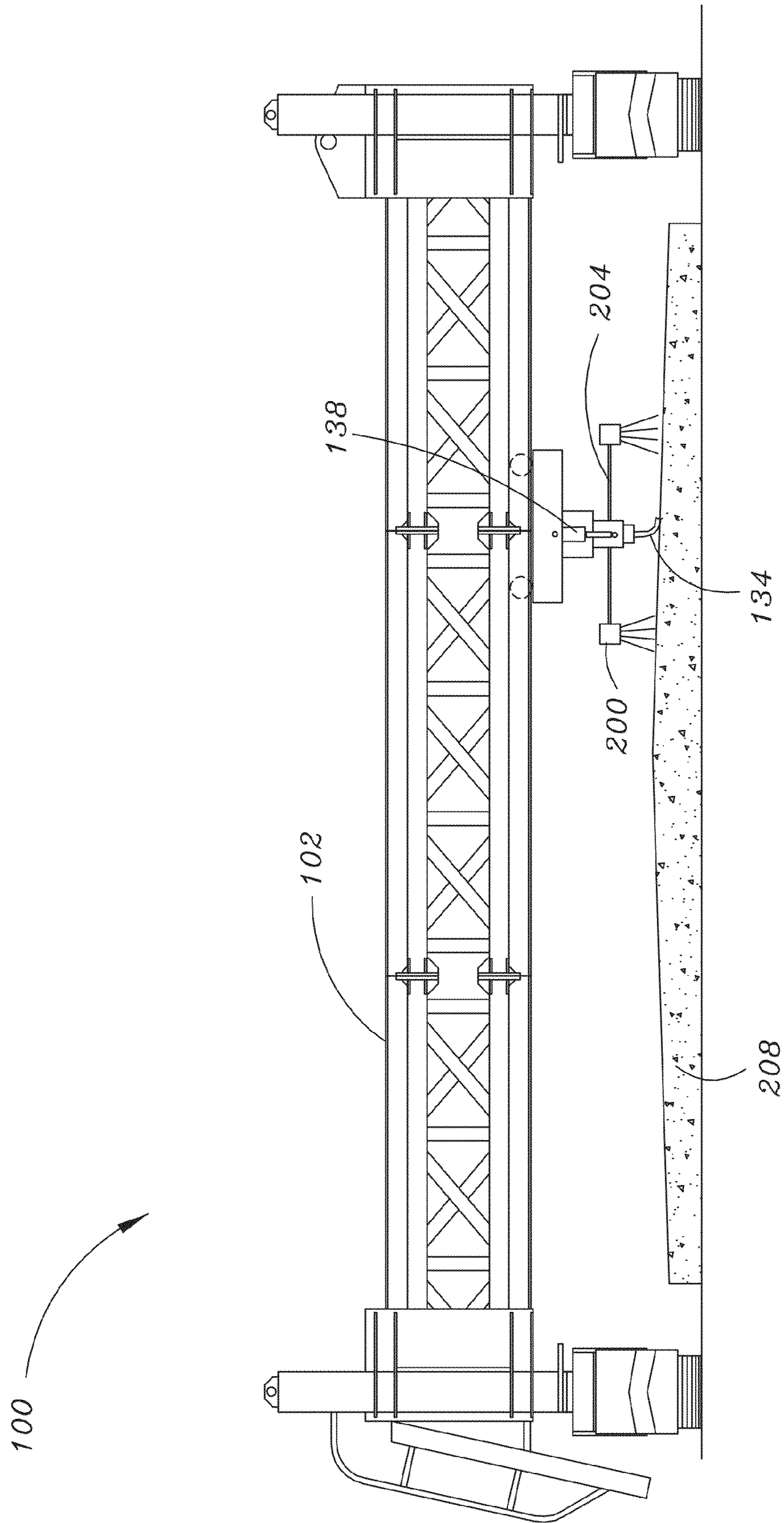


FIG. 21D

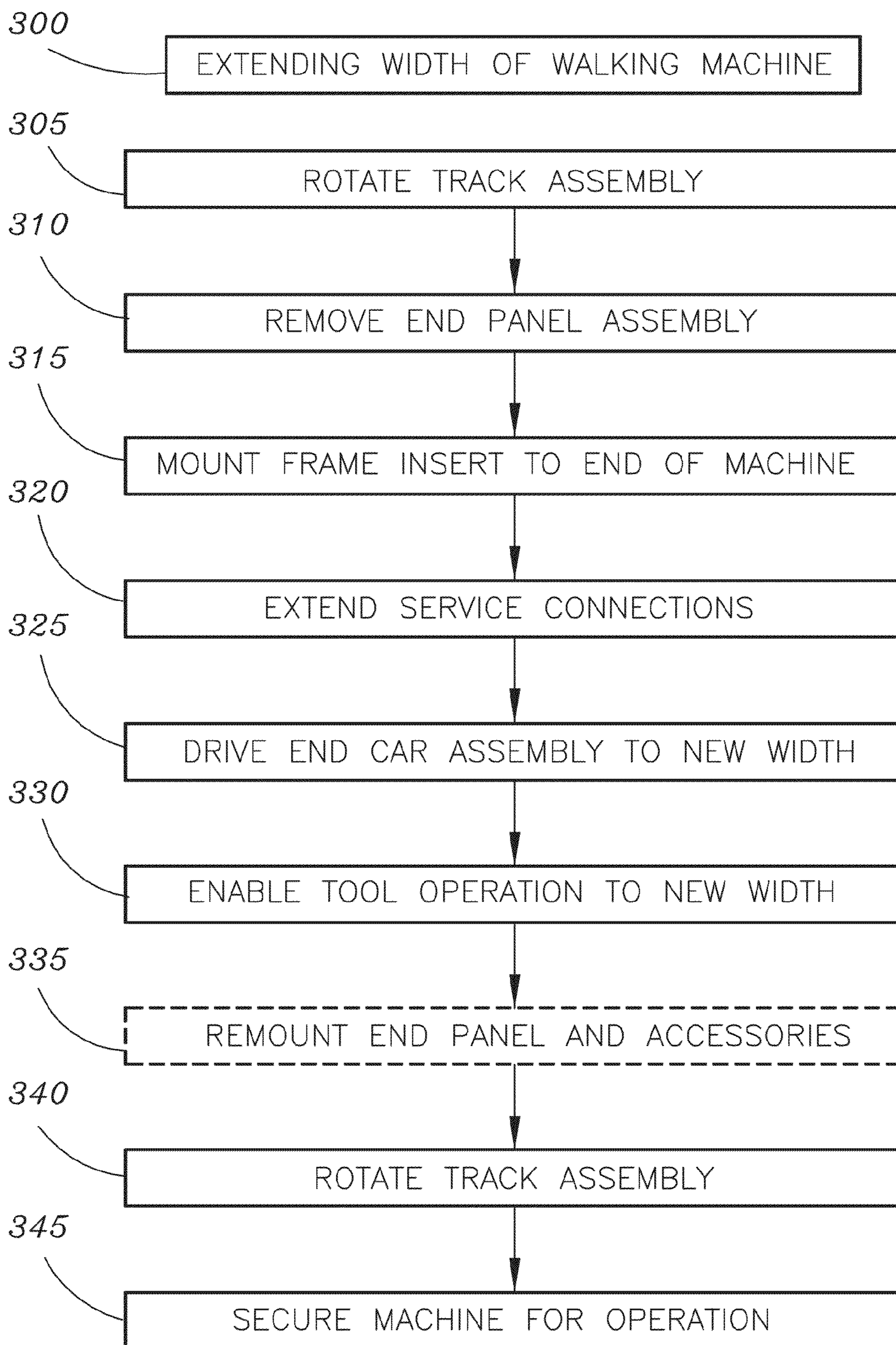


FIG. 22A



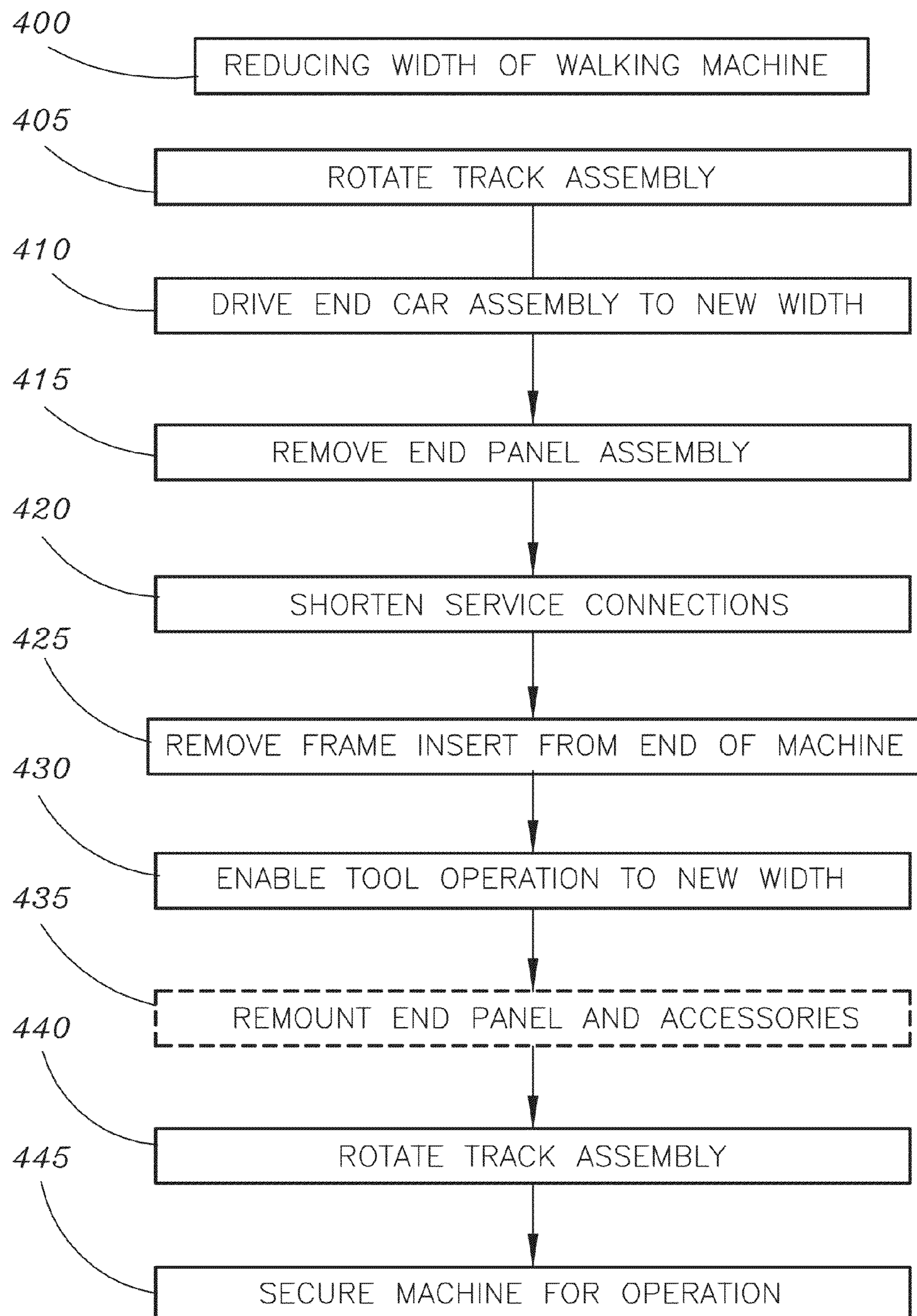


FIG. 22B

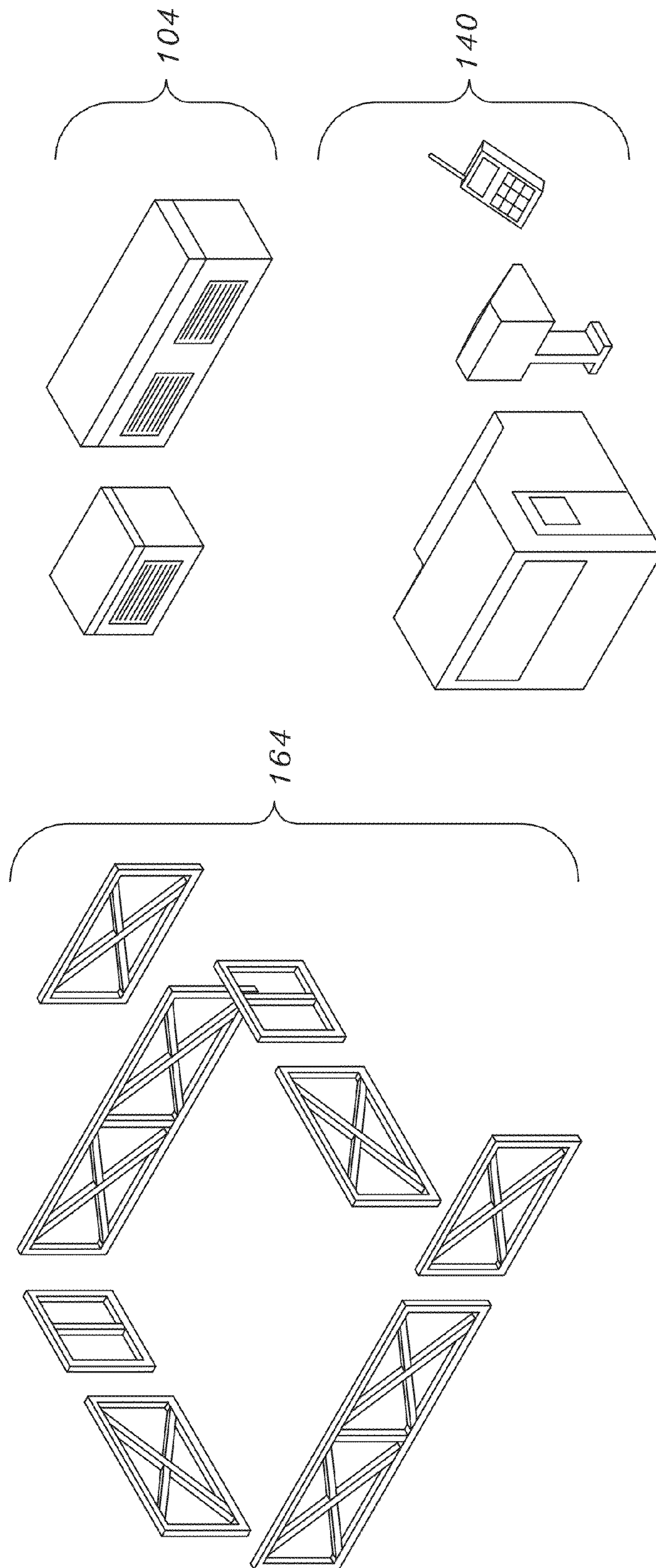


FIG. 23A

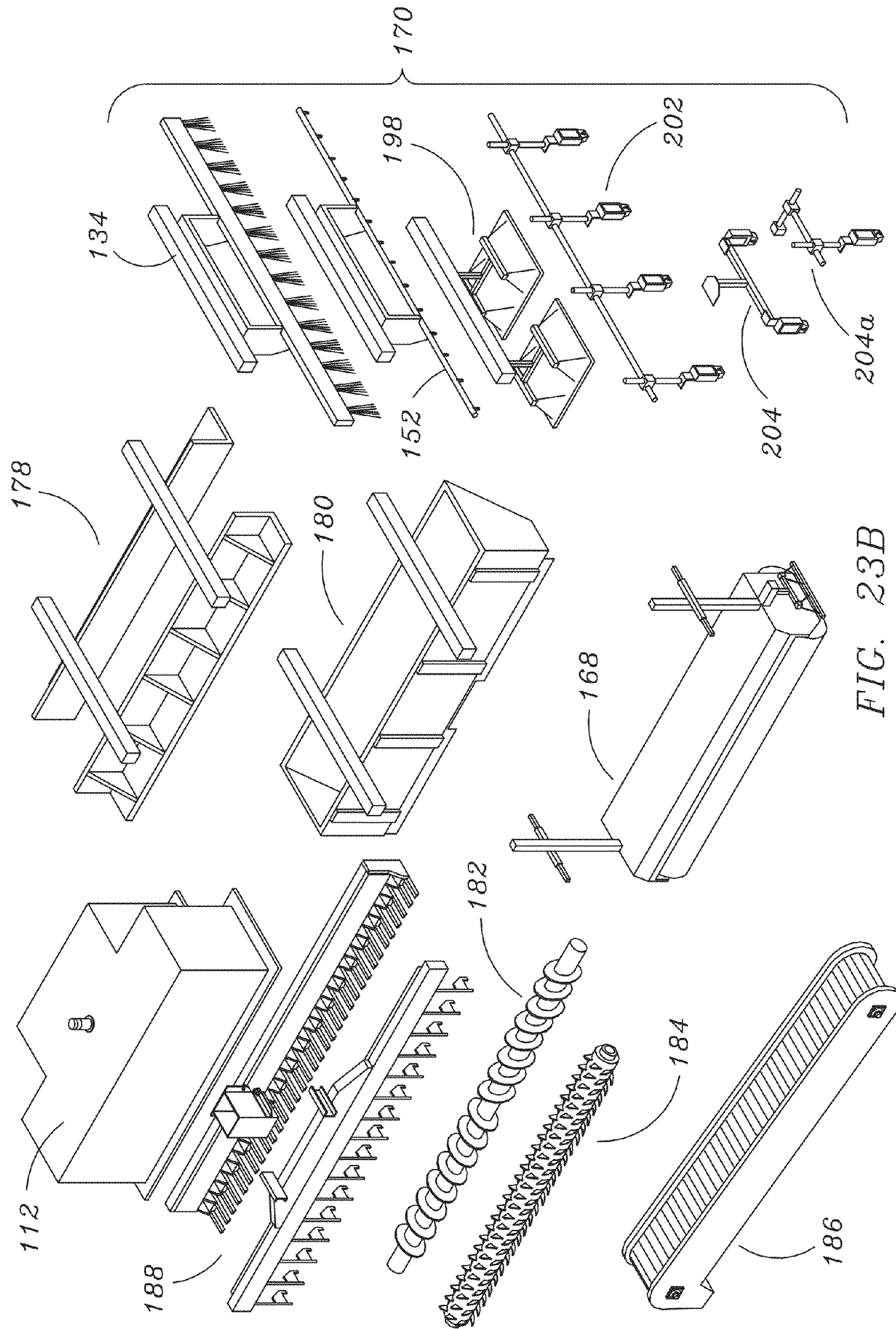


FIG. 23B



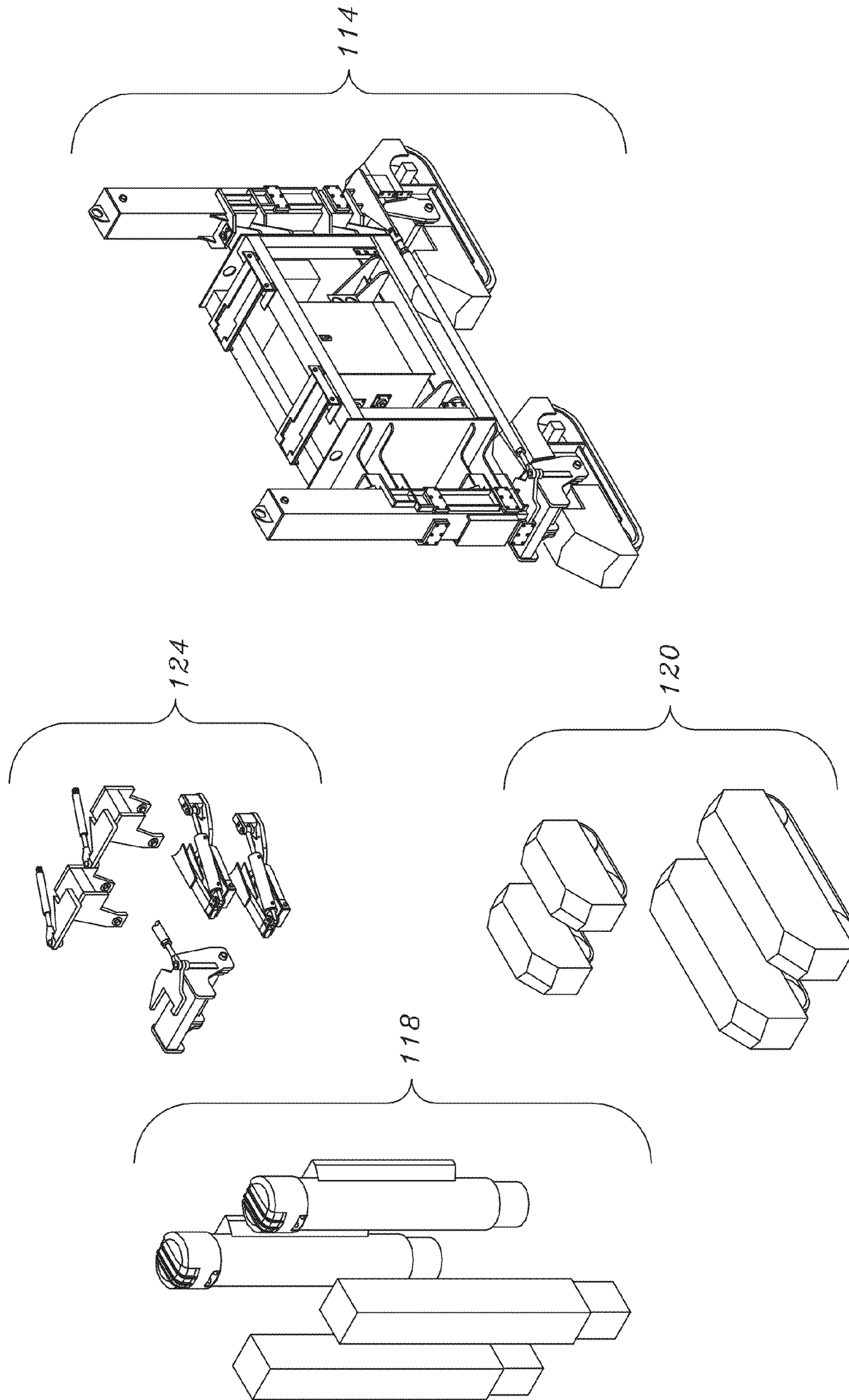


FIG. 23C

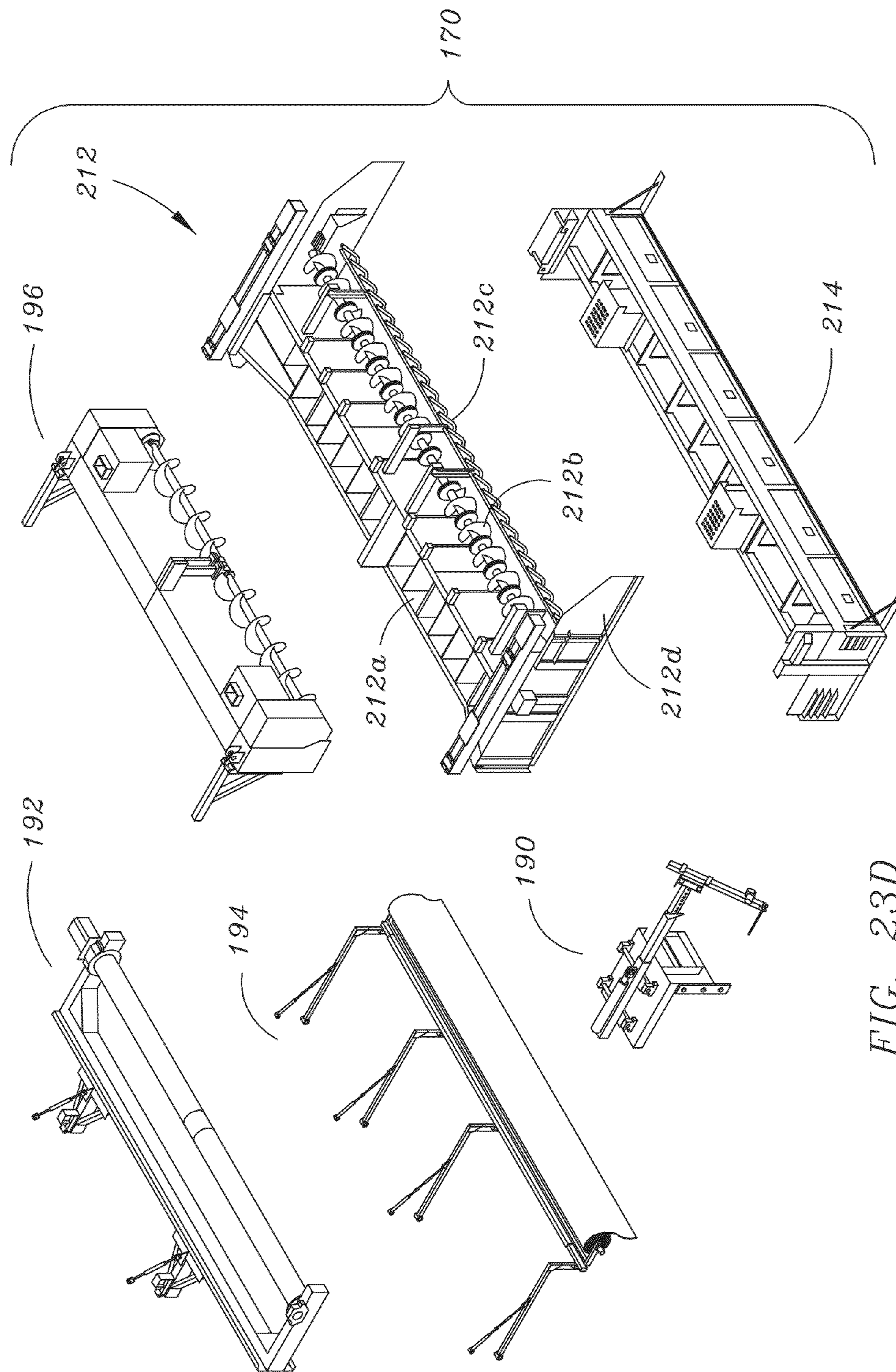


FIG. 23D



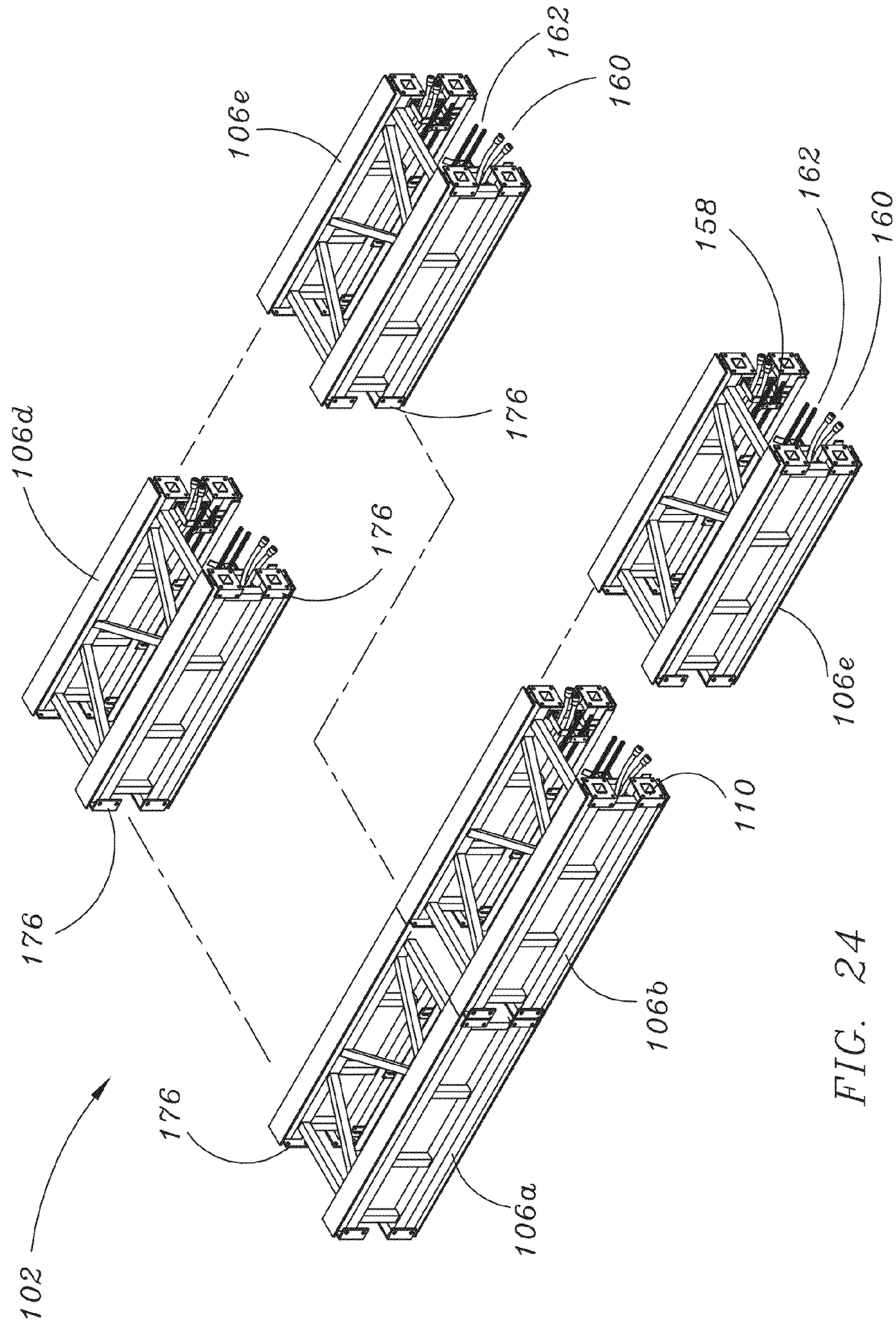
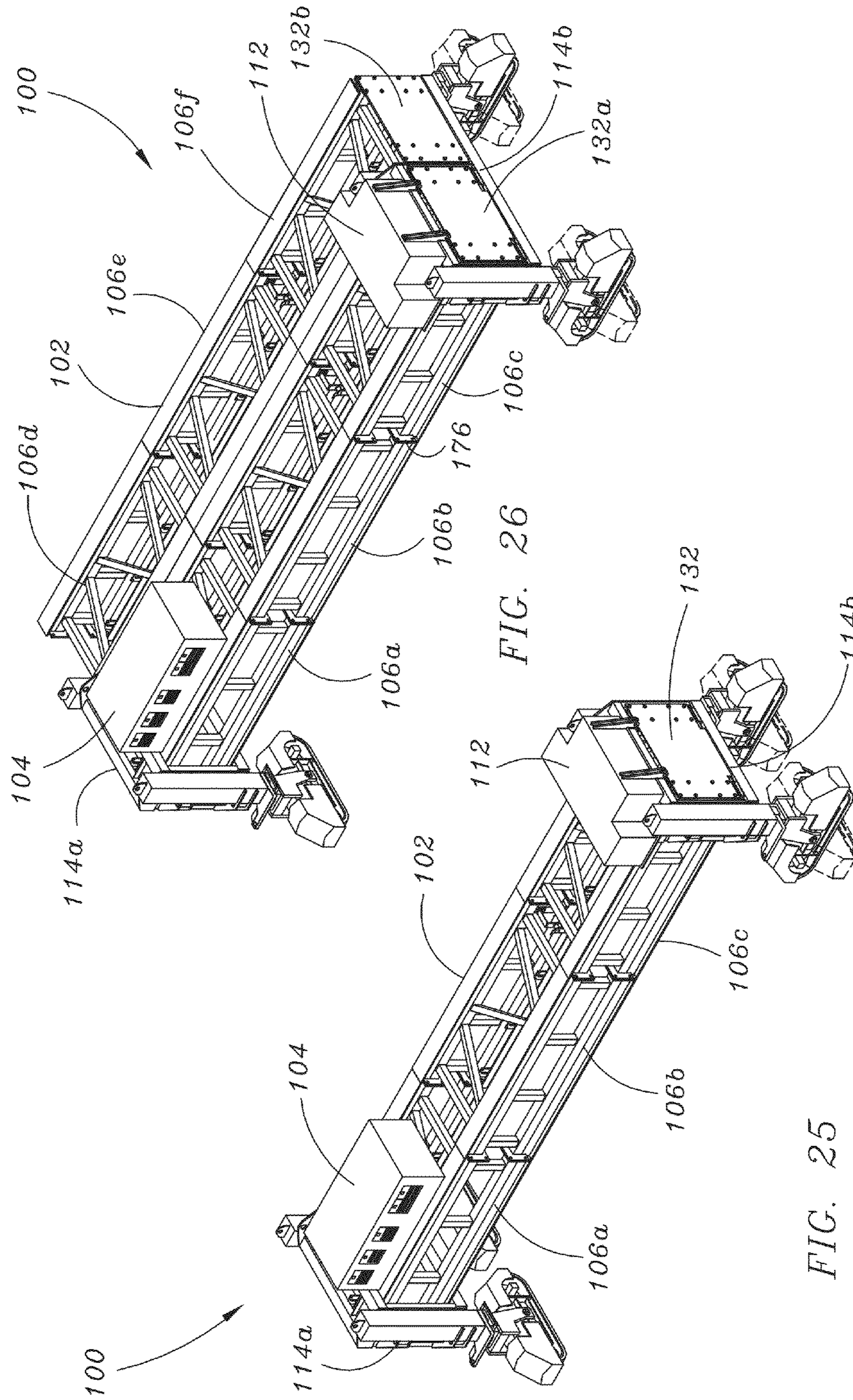


FIG. 24





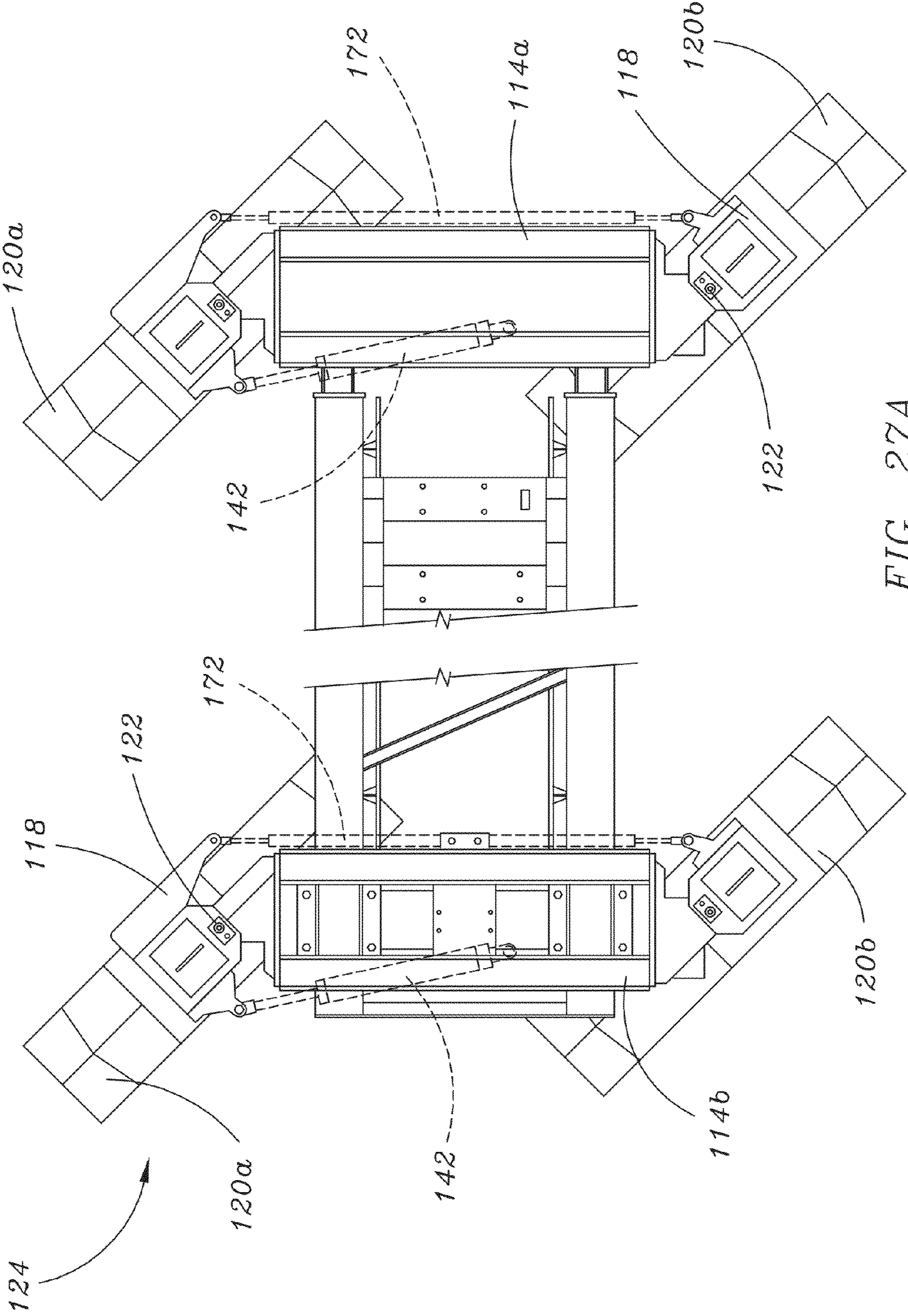


FIG. 27A

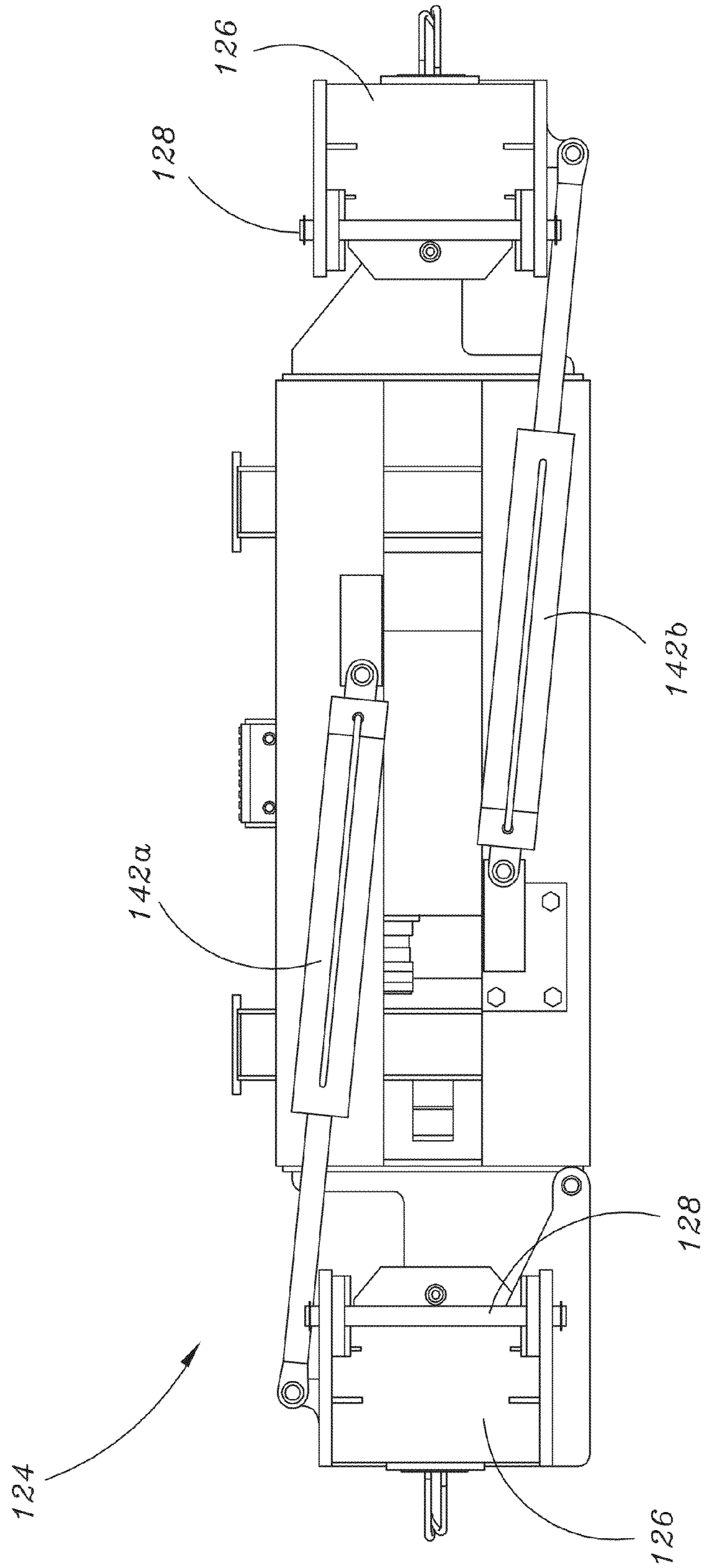


FIG. 27B



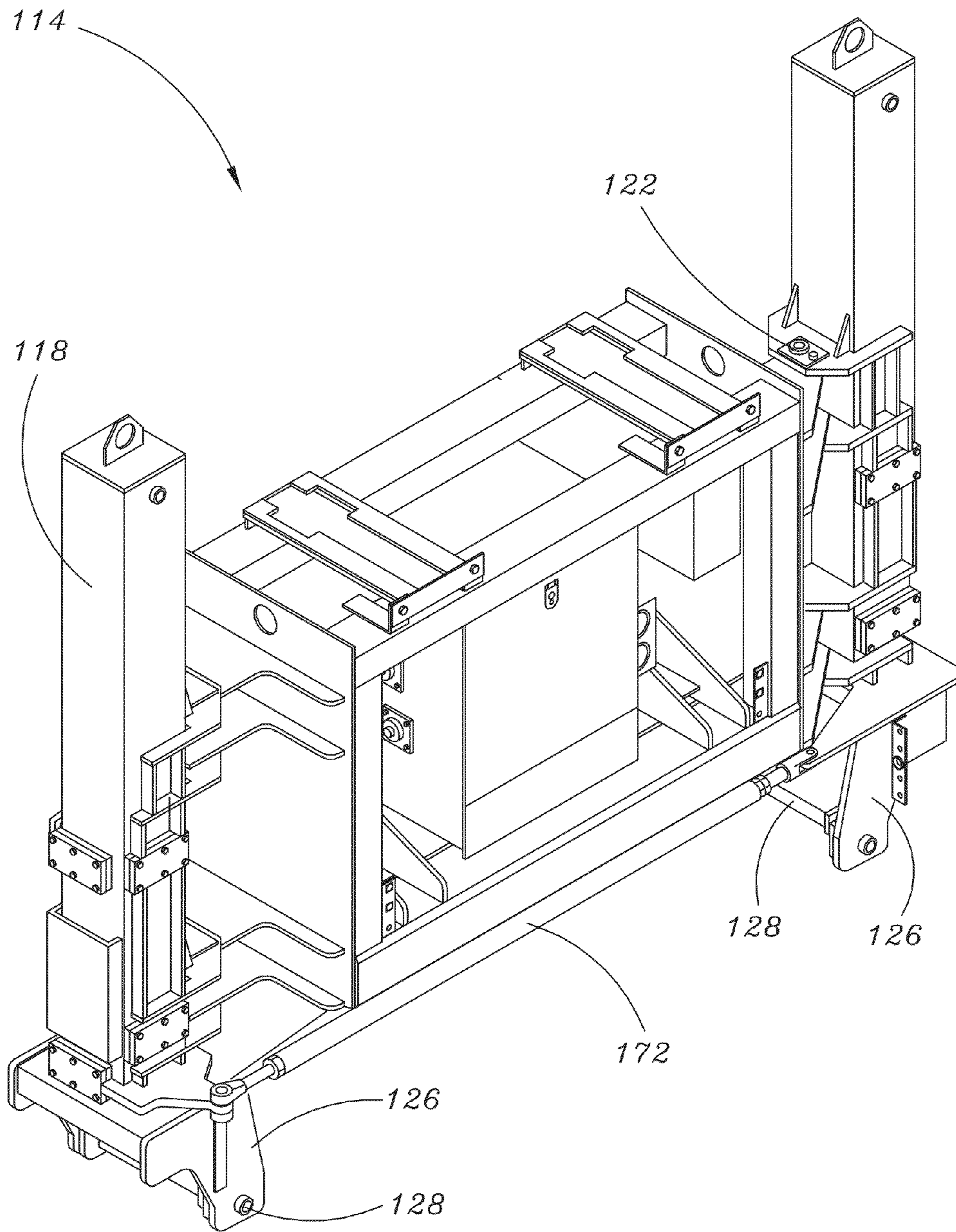


FIG. 28A

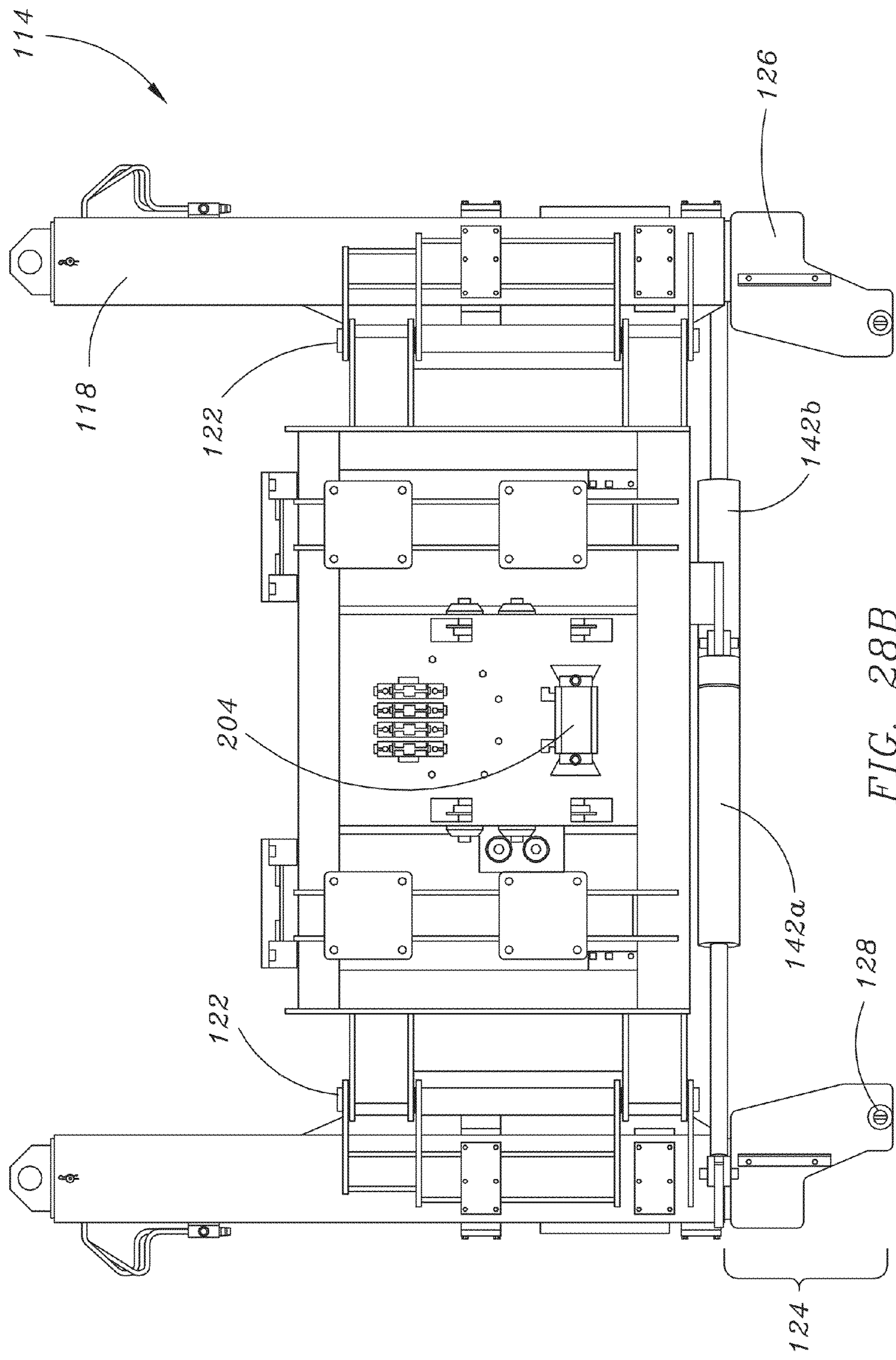


FIG. 28B



## 1

**MODULAR CONFIGURABLE PAVING  
APPARATUS AND MODULAR  
CONFIGURABLE PAVING OPERATION  
SYSTEM**

CROSS-REFERENCE TO RELATED  
APPLICATIONS

The present application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application Ser. No. 61/760,442, filed Feb. 4, 2013. Said U.S. Provisional Application is herein incorporated by reference in its entirety.

TECHNICAL FIELD

The present invention relates generally to the field of paving operations, and more particularly to paving machines with component/assembly modularity for ease of manufacture, improved user reconfigurability, and improved transportability.

BACKGROUND

Paving machines (such as texture/cure machines or like paving operations systems) are typically 2-track or 4-track (incorporating single-track or double-track end cars respectively), single-beam or multiple-beam, a first width or a second width, a first length or a second length, or a single tool, dual tool, or multi-tool (accessory). Two-track machines skid steer with the potential for variance in the perpendicularity of the machine to the slab, causing distortions to the parallelism of the grooves to the slab's edge. 4-track steerable machines negate this shortcoming with increased complexity.

Paving depth, surface preparation, transitions (slope and slab) and the like have traditionally been controlled by grade control with or without a hinge mechanism (crown transitions). Transition Adjustment (TA) sections add much in the way of cost and complexity to the frame. Groove depth error is subject to error in the control of crown angle in both the paver and the texture machines.

Paving equipment, including most paving machine frameworks and components, are generally designed and constructed to accommodate varying surface widths and/or tools/accessories. This is done through combinations of fixed-width modular structures and telescoping modular structures. A fixed structural support or bolster is fitted to the end of the machine framework by joining it to the grade control legs. End cars or other end structures must be detached to add or remove fixed-width frame members, and telescoping structures used for width changes add cost and complexity.

SUMMARY

Embodiments of the present invention are directed to a paving operations system having a modular framework that incorporates a rail system to facilitate mounting of accessories/components and support of the framework by an end structure, or end car, at either end of the framework. This allows for repositioning an end structure relative to the modular framework and adjusting the operating width of the system without the complexity of a telescoping frame member. The end structure and accessories may be moved along the framework by lateral sliding action along the rail system. Additional modular frame members may be added to or removed from the main framework's outside end without removal of end structure, which is simply moved along the framework to its new position.

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Preferred embodiments of the paving operations system incorporate a steering assembly at each end structure configured to convert the system between an operational/paving configuration and a transitional configuration. The steering assembly can utilize sensor-equipped steering cylinders to rotate steerable crawlers mounted to the end structures individually or in unison. Through a control system, the steering assembly can direct the position of the system and make precise steering corrections. The steering assembly can also position the steerable crawlers on one side of the system for lateral movement of an end structure along the modular framework to a new position.

In preferred embodiments, the modular framework of the system may be fitted with or connected to a range of accessories such as materials pans, spreader plows, longitudinal and transverse texture rakes, dowel bar inserters, burlap drags, pavement cure distributors, finishing screeds, or surface trimming systems. A paving operations system thus assembled from a selection of modular components and accessories can accommodate a diverse range of functionalities through a single base apparatus. For example, embodiments of the system may include an undercarriage fitted with pan and spreader accessories for paving a surface. Undercarriage accessories can then be swapped out for texturing accessories connected to the control system for precise tining and crowning, and later swapped out again for pavement curing accessories. In embodiments, the system incorporates sonic slab tracking and closed loop control of the grooving rake's position in addition to the machine's grade control to govern tining depth both for longitudinal and transverse grooves through any crown variance. Such a configuration preferably permits precise control without the added complexity of hinge mechanisms for crowning.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not necessarily restrictive of the invention as claimed. The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and together with the general description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages of the invention may be better understood by those skilled in the art by reference to the accompanying figures in which:

FIG. 1 is a perspective view of a four-track paving operations system having a readily extendable transverse width adjustment according to an embodiment of the present invention;

FIG. 2 is a perspective view of an embodiment of the four-track paving operations system extended by the addition of a frame member;

FIG. 3A is a front elevational view of an embodiment of the paving operations system in an operational/paving configuration;

FIG. 3B is an end elevational view of an embodiment of the paving operations system in an operational/paving configuration illustrating means for attaching an additional frame insert to a walking end car;

FIG. 4A is a front elevational view of an embodiment of the paving operations system with an end car in an operating/paving configuration and an end car in a transitional configuration;



FIG. 4B is an end elevational view of an embodiment of the paving operations system in a transitional configuration illustrating means for attaching an additional frame insert to a walking end car;

FIG. 5A is a front elevational view of an embodiment of the paving operations system in a transitional configuration with a walking end car and an additional frame insert attached;

FIG. 5B is a front elevational view of an embodiment of the paving operations system in a transitional configuration with a hydraulically driven walking end car and an additional frame insert attached;

FIG. 6 is a front elevational view of an embodiment of the paving operations system in a transitional configuration with a walking end car shown traversing an additional frame insert to extend transverse width;

FIG. 7A is a front elevational view of an embodiment of the paving operations system in an transitional configuration with a walking end car at the end of an additional frame insertion;

FIG. 7B is a front elevational view of an embodiment of the paving operations system in an operational/paving configuration with a walking end car at the end of an additional frame insertion;

FIG. 8 is a partial perspective end view of an embodiment of the paving operations system illustrating removal of an attachment plate for insertion of an additional frame member;

FIG. 9A is a perspective view of a modular frame insert of an embodiment of the present invention;

FIG. 9B is a perspective view of a modular frame insert of an embodiment of the present invention;

FIG. 10A is a front elevational view of a modular frame insert of an embodiment of the present invention;

FIG. 10B is an end elevational view of a modular frame insert of an embodiment of the present invention;

FIG. 11A is a front elevational view of a modular frame insert of an embodiment of the present invention;

FIG. 11B is an end elevational view of a modular frame insert of an embodiment of the present invention;

FIG. 12 is a partially exploded perspective view of a modular frame insert and end car assembly of an embodiment of the present invention;

FIG. 13 is a partially exploded perspective view of a modular frame insert, end car assembly, and attachment plate of an embodiment of the present invention;

FIG. 14 is a perspective view of a modular frame insert, end car assembly, and attachment plate of an embodiment of the present invention;

FIG. 15 is an end cross-sectional elevation of the construction and interface with the T-rail engagement assembly of a walking end car of the rail system of an embodiment of the present invention;

FIG. 16 is an end elevational view of the construction and interface with the T-rail engagement assembly of a walking end car of the rail system of an embodiment of the present invention;

FIG. 17 is an end cross-sectional elevation of the construction and interface with the T-rail engagement bearing assembly of a walking end car of the rail system of an embodiment of the present invention;

FIG. 18 is an end elevational view of the construction and interface with an alternative rail system of a walking end car of the rail system of an embodiment of the present invention;

FIG. 19 is a rear elevational view of an embodiment of a spray bar attachment of the present invention;

FIG. 20 is a front elevational view of an embodiment of a spray bar attachment of the present invention;

FIG. 21A is a front elevational view of a prior art texturing accessory;

FIG. 21B is a front elevational view of a prior art texturing accessory;

FIG. 21C is a front elevational view of an alternative embodiment of a texturing attachment of the present invention;

FIG. 21D is a front elevational view of an alternative embodiment of a texturing attachment of the present invention;

FIG. 22A is a flow diagram of an operation extending transverse width of an embodiment of the present invention;

FIG. 22B is a flow diagram of an operation reducing transverse width of an embodiment of the present invention;

FIG. 23A is a diagrammatic perspective view of the components and accessories of an embodiment of a paving operations system of the present invention;

FIG. 23B is a diagrammatic perspective view of the components and accessories of an embodiment of a paving operations system of the present invention;

FIG. 23C is a diagrammatic perspective view of the components and accessories of an embodiment of a paving operations system of the present invention;

FIG. 23D is a diagrammatic perspective view of the components and accessories of an embodiment of a paving operations system of the present invention;

FIG. 24 is a perspective view of an alternative embodiment of the modular framework of the present invention;

FIG. 25 is a perspective view of an embodiment of a paving operations system of the present invention;

FIG. 26 is a perspective view of an alternative embodiment of a paving operations system of the present invention;

FIG. 27A is a top elevational view of an embodiment of a steering assembly of the present invention;

FIG. 27B is a bottom elevational view of an embodiment of a steering assembly of the present invention;

FIG. 28A is an end elevational view of an embodiment of an end frame of the present invention; and

FIG. 28B is an end elevational view of an embodiment of an end frame of the present invention.

#### DETAILED DESCRIPTION

Features of the present invention in its various embodiments are exemplified by the following descriptions with reference to the accompanying drawings, which describe the present invention with further detail. These drawings depict only selected embodiments of the present invention, and should not be considered to limit its scope in any way.

FIG. 1 depicts an embodiment of a paving operations system 100 of the present invention. System 100 includes a modular framework 102 supported at either end by drive end car 114a and walking end car 114b. Modular framework 102 includes individual frame members 106a and 106b. In preferred embodiments, modular framework 102 incorporates structural tube or lattice type framing, and individual frame members 106 may be assembled from prefabricated and pre-sized frame panels 164. Frame members 106a and 106b include a series of frame mount flanges 110, by which frame members 106a and 106b may be bolted to each other or to end cars 114a and 114b via attachment plate 132. In embodiments, modular framework 102 includes a rail system 116 along its top and bottom sides for mounting accessories to modular framework 102 as well as support of the framework by end cars 114a and 114b. Individual rails mounted on frame members 106a and 106b seamlessly contact each other at frame joint 108, where frame members 106a and 106b con-



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nect. Rail system **116** allows for simplified system width adjustment via positioning end car **114b** relative to modular framework **102** without the complexity of a telescoping frame member. In preferred embodiments, rail system **116** is a T-rail system along which end cars **114a** and **114b** are configured to laterally slide. Rail system **116** may also incorporate alternative rail/slot designs or guide systems. Additional frame members **106** may be added to, or removed from, modular framework **102** without the detachment of walking end car **114b**. System **100** may also include a gasoline engine, diesel engine, or other like engine console **104** bolted to the frame insert **106a** directly connected to drive end car **114a**. System **100** may similarly include a cure tank or other accessory pod **112** bolted to the frame insert **106b** directly connected to walking end car **114b**. When not bolted to frame insert **106b**, accessory pod **112** can further slide along rail system **116** for repositioning. In embodiments, accessory mount **136** may be connected to the underside of modular framework **102**. Accessory mount **136** may, for example, accommodate a texture rake **134** for transverse or longitudinal tining operations, a spray bar assembly **152** for use in conjunction with cure tank **112**, or other like functional accessories.

Referring to FIG. 2, drive end car **114a** and walking end car **114b** further include front and rear legs **118** at each end of system **100** for vertical support. Each leg **118** is equipped with a steerable crawler **120** (including track **130**, fender, drive, and drive assembly). In some embodiments, front and rear legs **118** may be configured to hydraulically raise or lower modular framework **102** above ground level. In preferred embodiments, engine console **104** is bolted to the frame member **106a** directly connected to drive end car **114a**, and accessory pod **112** is bolted to the frame member **106c** directly connected to walking end car **114b**. Modular framework **102** may include an additional frame member **106b** as a result of an operation to extend the width of system **100** and an accessory mount **136** to which texture rake **134** has been transversely mounted. Preferred embodiments of accessory mount **136** can accommodate other accessories or a longitudinally mounted texture rake **134**.

Referring to FIGS. 3A and 3B, embodiments of paving operations system **100** may be transitioned into several useful configurations. FIG. 3A illustrates an embodiment of system **100** in an operational/paving configuration. Front steerable crawlers **120** mounted to adjustable legs **118** may be rotated by track mount yokes **126** to an operating orientation both substantially perpendicular to modular framework **102** and substantially parallel to a working surface. Tracks **130** of steerable crawlers **120** contact the ground as system **100** travels along the working surface while a control system electronically maintains the perpendicularity of system **100** to the working surface. In preferred embodiments, operator console **140** may be secured to modular framework **102** to provide the operator of system **100** with a means of interfacing with and directing the control system of system **100**. In preferred embodiments, the control system of system **100** may include the control system substantially disclosed in provisional application 61/760,416, herein incorporated in its entirety, or any like combination of hardware and software for controlling the components of system **100**. Referring to FIG. 3B, in embodiments of system **100** both front and rear steerable crawlers **120** connected to walking end car **114b** may be configured to steer in unison or individually to maintain system **100** in an orientation substantially parallel to the direction of travel along a work surface.

Referring to FIGS. 4A and 4B, in embodiments of system **100** the control system can convert system **100** to a transitional configuration for the addition or removal of frame

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members or other accessories or for the transport of system **100**. Front and rear steerable crawlers **120** connected to end cars **114a** and **114b** may be rotated by track mount yokes **126** to a transport orientation substantially parallel to the transverse width of modular framework **102**, and substantially perpendicular to the operational direction of travel of system **100**. Referring to FIG. 4B, an attachment plate may be removed from walking end car **114b** to expose frame mount flanges **110** of frame member **106b** for attachment of an additional frame member. In alternative embodiments, an attachment plate may be secured to frame mount flanges **110** of frame member **106b** as a step in reducing the width of system **100**.

FIGS. 5A and 5B illustrate an embodiment of system **100** after a primary stage of width extension, subsequent to the attachment of additional frame member **106c**. Referring to FIG. 5A, system **100** is in a transitional configuration, as shown by the transverse orientation of steerable crawlers **120** connected to walking end car **114b**. For transport and/or reconfiguration, orientation of both end cars **114** is preferably generally or substantially parallel (not perpendicular) both to each other and to modular framework **102** (FIGS. 4A, 5B, 6, 7A, 25, and 26). Walking end car **114b** remains in a position substantially flush with frame mount flanges **110b** of frame member **106b**. Additional frame member **106c** can then be connected to frame member **106b** via frame mount flanges **110b**, as frame member **106b** is connected to frame member **106a** via frame mount flanges **110a**; in preferred embodiments frame members **106b** and **106c** are bolted together. In alternative embodiments, frame member **106c** may be detached from frame member **106b** as an intermediate step in reducing the width of system **100**.

Referring to FIG. 5B, in preferred embodiments walking end car **114b** may be hydraulically pushed/pulled (via hydraulic cylinders **216**) along modular framework **102** with or without walking (from attachment points **218**). System **100** remains in a transitional configuration; steerable crawlers **120** connected to walking end car **114b** have been rotated to a transverse orientation, parallel to modular framework **102**, while steerable crawlers **120** connected to drive end car **114a** remain perpendicular to modular framework **102**. In preferred embodiments, steerable crawlers **120** connected to drive end car **114a** may be rotated to a transverse orientation parallel to modular framework **102** (and parallel to steerable crawlers **120** connected to walking end car **114b**), thus converting system **100** to a transport configuration. Once converted to a transport configuration, system **100** may then be driven onto another vehicle for transport. In embodiments, conversion of system **100** to transport configuration (i.e., rotation of both sets of steerable crawlers **120** to transverse orientation) may also be performed before walking end car **114b** is moved along modular framework **102** to a new position.

FIG. 6 illustrates an embodiment of system **100** of the present invention after a secondary stage of width extension. After frame member **106c** is attached to frame member **106b**, walking end car **114b** is moved along the transverse width of modular framework **102**. In embodiments, walking end car **114b** is configured to slide transversely along the rail system **116** of modular framework **102** to a position substantially flush with frame mount flanges **110c** of frame member **106c**. Walking end car **114b** may be walked manually along modular framework **102**, steered by the control system of system **100** in response to user input through operator console **140**, or propelled along modular framework **102** via one or more hydraulic cylinders **216**. In alternative embodiments, walking end car **114b** may be moved transversely in the direction of



drive end car **114a** in preparation for the removal of frame member **106c** in order to reduce the overall width of system **100**.

FIGS. 7A and 7B illustrate an embodiment of system **100** after a tertiary stage of width extension of the present invention. Referring to FIG. 7A, walking end car **114b** has been moved transversely along rail system **116** of modular framework **102** to a position substantially flush with frame mount flanges **110c** (not shown) of frame member **106c**, and attachment plate **132** has been secured to frame mount flanges **110c**. Accessory pod **112**, formerly secured to frame member **106b**, has been moved transversely along rail system **116** and secured to frame member **106c**. Any hydraulic hose extensions or other connections to accessory pod **112** or other components connected to walking end car **114b** may be re-connected or extended across frame member **106c**. Note that system **100** remains in a transitional configuration: front and rear steerable crawlers **120** connected to walking end car **114b** are oriented perpendicular to steerable crawlers **120** connected to drive end car **114a** and parallel to the transverse width of modular framework **102**.

Referring to FIG. 7B, as a final stage of a width extension operation of the present invention an embodiment of system **100** may be returned to an operational/paving configuration by rotating steerable crawlers **120** connected to end cars **114** (via track mount yokes **126**) to an operating orientation both perpendicular to modular framework **102**. In alternate embodiments, steerable crawlers **120** connected to end cars **114** may be rotated by track mount yokes **126** in an orientation parallel to the transverse width of modular framework **102** as a preliminary stage of reducing the width of system **100** by removing frame member **106c**.

FIG. 8 illustrates an embodiment of a primary stage of extending the width of modular framework **102** including converting system **100** to a transitional configuration (as shown by the transverse orientation of steerable crawlers **120** connected to walking end car **114b**). After attachment plate **132** is removed from walking end car **114b** to expose frame mount flanges **110a** of frame member **106a**, additional frame member **106b** can then be connected to frame member **106a** via frame mount flanges **110a** and **110b**. Once frame members **106a** and **106b** are connected, walking end car **114b** can then slide along the rail system **116** of modular framework **102**, (walked, driven or hydraulically propelled) to a desired position substantially flush with frame mount flanges **110c** of frame member **106b**.

FIGS. 9A and 9B illustrate an embodiment of frame member **106**. Referring to FIG. 9A, in preferred embodiments frame member **106** may include frame mount flanges **110** at both ends as well as a rail system **116** spanning frame member **106** along its top and bottom faces. Frame joint **108** marks the point at which rail system **116** of frame member **106** seamlessly connects with the rail system of an adjacent frame member so that end cars and other accessories may laterally slide along rail system **116** to a desired position. Referring to FIG. 9B, frame member **106** can also include internal guides **158** configured to hold in place hydraulic hoses **160** or other connectors **162** linking accessories or components of system **100**. In the event of an operation to extend the width of modular framework **102**, for example, extensions to any hydraulic hoses **160** or connectors **162** may be easily threaded through internal guides **158**.

FIGS. 10A and 10B illustrate an embodiment of frame member **106**. Referring to FIG. 10A, frame mount flanges **110** on either side of frame member **106** allow for secure connection of frame member **106** to other frame members or to attachment plate **132**. Rail system **116** spans frame member

**106** along its top and bottom faces, from frame joint **108a** to frame joint **108b**. Referring to FIG. 10B, interior guides **158** may be configured to secure hydraulic hoses or other connections in place through frame member **106**.

FIG. 11A illustrates a shorter embodiment of frame member **106** with correspondingly shorter rail system **116** and assembled from shorter frame panels **164a**, while FIG. 11B illustrates a longer embodiment of frame member **106** with a correspondingly longer rail system **116** and assembled from longer frame panels **164b**. Embodiments of frame member **106** may be assembled from prefabricated frame panels **164** of any appropriate length as construction needs dictate.

FIG. 12 illustrates an embodiment of frame member **106** detached from end car **114**. End car **114** may be configured to slide transversely along the rail system **116** of frame member **106** during width extension or width reduction operations of the present invention. Embodiments of end car **114** may also be configured to detach entirely from frame member **106** as a step of disassembling paving operations system **100** by sliding past frame mount flanges **110** and frame joint **108** at the end of frame member **106**.

FIGS. 13 and 14 illustrate an embodiment of modular framework **102**. Referring to FIG. 13, attachment plate **132** may be secured to the end of frame member **106** through the corresponding holes in frame mount flanges **110**; in preferred embodiments attachment plate **132** is bolted to frame mount flanges **110**. Attachment plate **132** can further be disconnected from frame member **106** as a preliminary step of extending or reducing the width of system **100** by the addition or removal of a frame member **106**.

FIG. 14 illustrates an embodiment of modular framework **102** in which attachment plate **132** has been secured to frame member **106** via frame mount flanges **110** (not shown) to hold end car **114** in place. In embodiments, attachment plate **132** is secured to frame member **106** as a final step of extending or reducing the width of system **100** by the addition or reduction of a frame member **106**.

FIGS. 15-18 depict embodiments of modular framework **102** in which end car **114** is slidably connected to frame member **106** by a rail system **116**. Referring to FIG. 15, in preferred embodiments rail guide **144** of end car **114** secures T-rail **116** in place while allowing end car **114** to slide along the length of T-rail system **116**. FIG. 16 illustrates the use of an alternate embodiment of rail guide **144** to accommodate T-rail system **116**. FIG. 17 illustrates an embodiment of modular framework **102** wherein rail guide **144** using a series of bearings **146** in contact with T-rail **116** to secure and slidably guide end car **114** along the length of T-rail system **116**.

In alternative embodiments of modular framework **102**, rail system **116** of frame member **106** may not include a T-rail system. Referring to FIG. 18, frame member **106** may include an alternative rail system **148** with a rounded slot, into which a corresponding rounded rail **150** of end car **114** is inserted, allowing end car **114** to slide along the length of alternative rail system **148**.

FIG. 19 illustrates a rear view of, and FIG. 20 illustrates a front view of, an embodiment of paving operations system **100** incorporating a spray bar assembly **152** secured to accessory mount **136**. Referring to FIG. 19, cure tank **112** may be mounted to end car **114b** and connected to spray bar assembly **152** for distribution to the work surface; in preferred embodiments, cure tank **112** is constructed of steel and is mounted to walking end car **114b** opposite engine console **104**.

Referring to FIG. 20, in preferred embodiments the control system of system **100** includes a spray control system that regulates the flow through nozzles **154** of spray bar assembly



152 via flow meters linked to the control system, speed sensors mounted to spray bar assembly 152, or in response to user input. Referring to FIG. 19, in some embodiments spray bar assembly 152 includes an aluminum walkway 156 mounted to the rear of modular framework 102. Embodiments of spray bar assembly 152 may fold up when system 100 converts to a transitional configuration. In preferred embodiments, spray bar assembly 152 and a texture rake 134 are the same length, e.g., 7 feet, so that tining and curing may occur simultaneously. Referring to FIG. 20, embodiments of engine console 104 may be configured to slide transversely along, and then mounted to other points on, modular framework 102.

In preferred embodiments, the control system of system 100 includes a tining control system. Embodiments of the tining control system may include acoustic or sonic sensors to track slab elevation so that a texture rake 134 mounted transversely may trace a work surface at a desired depth without the need for a power transition adjuster. The control system of system 100 can control the depth of texture rake 134 through a hydraulic height adjuster of the accessory mount 136. In preferred embodiments, the hydraulic height adjuster can move the texture rake through a vertical range of 12 to 16 inches in response to information received through sensors or user input. The tining control system may also include proximity switches to control the end points of texture rake 134. Embodiments of the tining control system can also include centrally mounted acoustic or sonic sensors for monitoring grade elevation. Grade elevation sensors enable the control system to control the height and orientation of a longitudinally mounted texture rake 134 during pavement tining or crowning operations. Embodiments of the control system may also include a grade control system, a trimming control system, a smoothness indicator control system, or any other control system component configured to control an accessory of system 100.

FIGS. 21A-21D illustrate an alternative embodiment of a texturing attachment for a paving operations system 100 of the present invention. Referring to FIG. 21A, system 100 may be fitted with an accessory mount 136 to which a texture rake 134 may be mounted for transverse texturing of a flat surface 206. The control system of system 100 may direct texture rake 134 to move transversely across surface 206, texturing the surface to a desired depth. Referring to FIG. 21B, system 100 may be configured to texture a crowned surface 208. Paved surface 208 may be crowned, i.e., descend in height from a central apex 210, so that water may flow downward away from the apex 210 and efficiently drain surface 208. Power transition adjuster 166 may therefore be mounted to system 100 and configured to crown the modular framework 102 of system 100 to match crowned surface 208, so that texture rake 134 connected to accessory mount 136 may transversely move across and texture surface 208 to a uniform desired depth.

FIG. 21C illustrates an alternative embodiment of paving operations system 100. In preferred embodiments, system 100 may include a hydraulic height adjuster 138 and sensor array 204 mounted to accessory mount 136. Sensor array 204 may include at least one slab elevation sensor 202 transversely mounted to texture rake 134 and configured to return data on the elevation of flat surface 206 to the control system. FIG. 21D illustrates an alternative embodiment of paving operations system 100 texturing a crowned surface 208. Rather than utilize a power transition adjuster, system 100 may reduce complexity by mounting hydraulic height adjuster 138 and sensor array 204 to accessory mount 136 in addition to texture rake 134. As accessory mount proceeds

transversely across crowned surface 208, transversely mounted slab elevation sensors 200 provide data to the control system which in turn controls hydraulic height adjuster 138. In preferred embodiments, hydraulic height adjuster 138 can raise or lower accessory mount 136 (and texture rake 134) through a continuous vertical range of 12 to 16 inches, allowing texture rake 134 to transversely texture crowned surface 208 at a uniform or desired depth.

FIG. 22A illustrates a method 300 for extending the width of an embodiment of paving operations system 100. At step 305 of method 300, steering assembly 124 articulates leg pivots 122 to rotate front and rear steerable crawlers 120 connected to walking end car 114b to a transport orientation parallel to modular framework 102, transitioning system 100 to transitional configuration. At step 310, attachment panel 132 is removed from the frame member 106b farthest from drive end car 114a. At step 315, an additional frame insert 106c is mounted to frame insert 106b via frame mount flanges 110. At step 320, hydraulic hoses 160 and other service connections 162 are extended across the length of additional frame member 106c. At step 325, walking end car 114b is driven along rail system 116 of additional frame member 106c to a position substantially flush with frame mount flanges 110 at the outer end (i.e., farthest from drive end car 114a) of additional frame member 106c. At step 330, operation of any tools and components is enabled for the new extended width of modular framework 102. At step 335, attachment panel 132 and any accessories 112 are mounted to additional frame member 106c. At step 340, steering assembly 124 articulates leg pivots 122 to rotate front and rear steerable crawlers 120 connected to walking end car 114b to an operating orientation perpendicular to the width of modular framework 102, transitioning system 100 to an operational/paving configuration. Finally, at step 345, paving operations system 100 is secured for operation.

FIG. 22B illustrates a method 400 for reducing the width of an embodiment of paving operations system 100. At step 405 of method 400, steering assembly 124 articulates leg pivots 122 to rotate front and rear steerable crawlers 120 connected to walking end car 114b to a transport orientation parallel to the transverse width of modular framework 102, transitioning system 100 to transitional configuration. At step 410, walking end car 114b is driven along outermost frame member 106c to a position substantially flush with frame mount flanges 110 at the outer end of penultimate frame member 106b. At step 415, attachment plate 132 is removed from outer frame member 106c. At step 420, hydraulic hoses 160 and other service connections 162 are shortened to penultimate frame member 106b. At step 425, outermost frame insert 106c is detached from modular framework 102. At step 430, operation of any tools and components is enabled for the new reduced width of modular framework 102. At step 435, attachment panel 132 and any accessories 112 are mounted to new outermost frame member 106b. At step 440, steering assembly 124 articulates leg pivots 122 to rotate front and rear steerable crawlers 120 connected to walking end car 114b to an operational orientation perpendicular to the width of modular framework 102, transitioning system 100 to operational/paving configuration. Finally, at step 445, paving operations system 100 is secured for operation.

FIGS. 23A, 23B, 23C, and 23D illustrate modular components and accessories 170 of an embodiment of paving operations system 100. In some embodiments, paving operations system 100 may be modularly manufactured or modularly configured in the field from a selection of prefabricated components to maximize the versatility and functionality of a single base apparatus. Referring to FIG. 23A, accessories 170



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may include individual frame panels **164** (from which frame members **106** may be assembled) of various lengths and levels of interior support. Engine consoles **104** may include gasoline, diesel, or electric power sources of various sizes and power ratings. Operator consoles **140** may include standard control stations, portable control consoles mountable to any part of the modular framework, and remote control units.

Referring to FIG. **23B**, accessories **170** attachable to accessory mount **136** or modular framework **102** may include accessory pod/cure tank **112**, longitudinal or transverse texture rakes **134**, spray bar assemblies **152**, slipformers **178**, transverse saw/bridge deck finishers **168**, paving pans **180**, spreading augers **182**, trimmer wheels **184**, placer conveyors **186**, dowel bar inserters **188**, finishing pans **198**, individual sensors **202**, or arrays **204** of multiple sensors. Sensor arrays **204** may be mounted transversely (for slab elevation tracking in crowning operations) or longitudinally (for grade elevation). Sensor arrays may further include single adjustable spot sensors **204a** mounted to the undercarriage or to another accessory. Individual sensors **202** may be mounted to another accessory or to system **100** in order to return data associated with a geographic reference of system **100**, a position relative to system **100**, the position of a particular tool or accessory, a work surface position, or a work file position.

Referring to FIG. **23C**, steerable crawlers **120** may include tracks **130** of various sizes. Steering assemblies **124** may include single-cylinder, multiple-cylinder, and smart-cylinder leg pivots and assemblies, yoke/pin assemblies, and combinations of steering cylinders and tie rods. Adjustable legs **118** may include legs capable of raising and lowering the vertical height of modular framework **102** via hydraulic, electronic, and other means. End cars **114** may include combinations of end frame structures, adjustable legs **118**, steerable crawlers **120**, and steering assemblies **124**.

Referring to FIG. **23D**, further accessories attachable to accessory mount **136** or otherwise configurable to paving operations system **100** may include side bar inserters **190**, poly rollers **192**, burlap drags **194**, auger strike-offs **196**, auger strike-off assemblies **212** (incorporating slipformers **212a**, spreader **212b**, vibrating rods **212c**, and sideforms **212d**), and IDBI screeds **214**.

In some embodiments, paving operations system **100** may require a more substantial modular framework **102** due to the need for added accessories or increased stability. FIG. **24** illustrates a dual-frame embodiment of modular framework **102** incorporating two rows of frame members **106**. Frame member **106c** may be mounted longitudinally to frame member **106b** via frame mount flanges **110** to extend the width of modular framework **102**. In alternative embodiments, modular framework **102** may incorporate combination frame mount flanges **176**, allowing frame members **106d** and **106e** to be mounted transversely to frame members **106a** and **106b** and longitudinally to each other, extending the width of modular framework **102** as well as the length. Hydraulic hoses **160** and other connections **162** may then be extended through interior guides **158** on either side of the dual-frame modular framework **102**.

FIGS. **25** and **26** compare single-frame and dual-frame embodiments of paving operations system **100**. Referring to FIG. **25**, single-frame modular framework **102** incorporates frame members **106a**, **106b**, and **106c**. Power unit **104** is bolted to the frame member **106a** directly connected to drive end car **114a**, and accessory pod **112** is bolted to the frame member directly connected to walking end car **114b**, to which attachment plate **132** is similarly bolted. Referring to FIG. **26**, dual-frame modular framework **102** additionally incorporates frame members **106d**, **106e** and **106f** transversely

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mounted to frame members **106a**, **106b**, and **106c** respectively and longitudinally mounted to each other. In dual-frame embodiments of modular framework **102**, walking end car **114b** may have telescoping capability to accommodate multiple frame members **106**. Dual attachment plates **132a** and **132b** are bolted to frame members **106c** and **106f** respectively. In dual-frame embodiments, extending the transverse width of modular framework **102** may involve removal of attachment plates **132a** and **132b**, mounting of additional frame members **106** to frame members **106c** and **106f** (and to each other) via combination frame mount flanges **176**, moving walking end car **114b** laterally along modular framework **102** to a position substantially flush with open combination frame mount flanges **176** of the additional frame members **106**, and reattachment of attachment plates **132a** and **132b** to the additional frame members **106**.

FIGS. **27A** and **27B** illustrate alternative embodiments of steering assembly **124**. Operations to extend or reduce the width of system **100** may require the steerable crawlers **120** at one end of system **100** to steer independently, e.g., for moving an end car **114** along modular framework **102** to a new position while system **100** remains stationary. Similarly, transporting system **100** may require precision steering to maneuver system **100** onto a transport vehicle. Finally, embodiments of system **100** may benefit from electronically controlled crab steering in addition to skid steering for maintaining system **100** in a desired operating orientation while paving, texturing, etc. Referring to FIG. **27A**, fixed end cars **114a** or telescoping end cars **114b** may be connected to adjustable legs **118** via leg pivots **122**, and legs **118** are in turn connected to front steerable crawlers **120a** and rear steerable crawlers **120b**. In embodiments of steering assembly **124**, steering cylinder **142** may articulate front steerable crawler **120** to rotate in response to commands from the control system or a user. Steering tie rod **172**, connecting front steerable crawler **120a** to rear steerable crawler **120b**, may then articulate rear steerable crawler **120b** to rotate in unison with front steerable crawler **120a**.

Referring to FIG. **27B**, alternative embodiments of steering assembly **124** may incorporate dual steering cylinders **142a** and **142b** linked to a track mount yoke **126** and track pin **128**, which in turn articulates steerable crawlers **120**. In response to commands from the control system of system **100** or a user, steering cylinders **142a** and **142b** may articulate their respective steering tracks **120** to rotate in unison through track mount yoke **126** and track pin **128**. Steering cylinders **142a** and **142b** may also articulate a single steerable crawler **120** independently to provide precise crab steering corrections in operating and transitional configurations. In preferred embodiments, steering cylinders **142a** and **142b** are "smart" hydraulic steering cylinders equipped with sensors configured to continually relay position data to the control system. In preferred embodiments, the control system of system **100** incorporates a steering control system including system controls for electric over hydraulic steering and grade control. Steering assembly **124** may be configured to rotate one or both steerable crawlers **120** through a continuous 90-degree range from an operational orientation (a longitudinal orientation perpendicular to the modular framework) to a transport orientation (a transverse orientation parallel to the modular framework). In preferred embodiments, steering assembly **124** is configured to provide an additional 8 degrees of steering correction. The control system may make steering corrections in response to user input or based on sensor data. For example, a user may input crab steering corrections while configuring system **100** for transport, or the control system



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may correct steering based on data collected from grade elevation or slab elevation sensors during a texturing operation.

FIGS. 28A and 28B illustrate alternative embodiments of fixed end car 114. Referring to FIG. 28A, adjustable legs 118 may be mounted to end car 114 via leg pivots 122. Steerable crawlers 120 may then be mounted to legs 118 via track mount yoke 126 and track pin 128, so that steerable crawlers 120 may rotate around legs 118; legs 118 may pivot in order to allow steerable crawlers 120 greater mobility without manual adjustments to end car 114 or rerouting of hydraulics and other connections. Embodiments of end car 114 may include a steering assembly 124 incorporating one or more steering cylinders 142, smart steering cylinders, tie rods 172, or other like means for articulating steerable crawlers 120. Steering tie rod 172, for example, may articulate rear steerable crawler 120 in unison with front steerable crawler 120 when front steerable crawler 120 rotates in response to commands from a user or the control system of paving operations system 100.

Referring to FIG. 28B, alternative embodiments of end car 114 may include a steering assembly 124 incorporating dual steering cylinders 142a and 142b, each of which may be configured to articulate a single steerable crawler 120 via track mount yoke 126 and track pin 128. In response to user commands or the control system of paving operations system 100, both steering cylinders 142 may articulate in unison the front and rear steerable crawlers 120 mounted to end car 114 via adjustable legs 118 mounted to end car 114 via leg pivots 122. Embodiments of end car 114 may additionally incorporate a flow divider 204 for use in conjunction with cure tank 112 or spray bar assembly 152.

Those having skill in the art will appreciate that there are various vehicles by which processes and/or systems and/or other technologies described herein may be effected (e.g., hardware, software, and/or firmware), and that the preferred vehicle will vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle; alternatively, if flexibility is paramount, the implementer may opt for a mainly software implementation; or, yet again alternatively, the implementer may opt for some combination of hardware, software, and/or firmware. Hence, there are several possible vehicles by which the processes and/or devices and/or other technologies described herein may be effected, none of which is inherently superior to the other in that any vehicle to be utilized is a choice dependent upon the context in which the vehicle will be deployed and the specific concerns (e.g., speed, flexibility, or predictability) of the implementer, any of which may vary. Those skilled in the art will recognize that optical aspects of implementations will typically employ optically-oriented hardware, software, and or firmware.

The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively “associated” such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality may be seen as “associated with” each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated may also

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be viewed as being “connected”, or “coupled”, to each other to achieve the desired functionality, and any two components capable of being so associated may also be viewed as being “couplable”, to each other to achieve the desired functionality. Specific examples of couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

While particular aspects of the present subject matter described herein have been shown and described, it will be apparent to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from the subject matter described herein and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of the subject matter described herein.

We claim:

1. A configurable paving operations system, comprising:
  - a modular framework having a transverse width and including at least a first frame insert and a second frame insert, each frame insert having a first end including a connector and a second end including a connector, and at least one rail system along its length, the second end of the first frame insert removably coupled to the first end of the second frame insert via connector, wherein the transverse width of the modular framework is configured to at least one of extend via the addition of at least one frame insert and retract via the removal of at least one frame insert;
  - at least a first end structure and a second end structure, the first end structure coupled to the first end of the first frame insert and the second end structure at least one of coupled to the second end of the second frame insert and slidably coupled to the modular framework via the at least one rail system;
  - each end structure having at least an attachment plate couplable to a frame insert via connector, at least a first adjustable leg and a second adjustable leg coupled to the end structure, and a plurality of steerable crawlers including at least a first steerable crawler rotatably coupled to the first adjustable leg and a second steerable crawler rotatably coupled to the second adjustable leg selected from a plurality of steerable crawlers;
  - each end structure including a steering assembly operatively coupled to the plurality of steerable crawlers, configured to rotate at least one of the first steerable crawler and the second steerable crawler; and
  - a control system.

2. The system of claim 1, wherein each frame insert of the plurality of frame inserts has a size selected from a plurality of sizes, the size defined by at least one of a length, a width, a height, and a structural thickness.

3. The system of claim 1, wherein the control system includes at least one of a steering control system operably coupled to the at least one steering assembly, a propulsion control system, a trimming control system, a slope control system, a spray control system, a grade control system, a tining control system, a plurality of sensors, and a user interface.

4. The system of claim 3, wherein the at least one steering assembly includes at least one steering cylinder, each steering cylinder including at least one sensor communicatively coupled to the control system.

5. The system of claim 4, wherein the at least one steering cylinder is a hydraulic steering cylinder.



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6. The system of claim 4, wherein the at least one steering assembly includes at least one steering cylinder and at least one tie rod.

7. The system of claim 1, further comprising at least one accessory removably coupled to the modular framework.

8. The system of claim 7, wherein the at least one accessory is at least one of a cure tank, an engine console, a walkway, an operating platform, a sensor operably coupled to the control system, an undercarriage, a texture rake, a texture broom, a texture drag, a spray bar assembly, a roller, an auger, a spreader, a trimmer, a form, a mold, a pan, a finisher, a saw, a bar inserter, a screed, a placer, a conveyor, and a plow.

9. The system of claim 8, wherein the engine console is at least one of a gasoline engine and a diesel engine.

10. The system of claim 8, wherein the operating platform includes an operating console having a display unit and a user input device communicatively coupled to the control system.

11. The system of claim 8, wherein the undercarriage includes

a hydraulic height adjuster operably coupled to the control system and configured to at least one of raise and lower the undercarriage through a vertical range; and at least one accessory removably coupled to the undercarriage.

12. The system of claim 11, wherein at least two accessories may be removably coupled to the undercarriage simultaneously.

13. The system of claim 11, wherein the control system further comprises:

at least one sensor mounted to at least one of the undercarriage, hydraulic height adjuster, and the accessories; and at least one proximity sensor mounted to the at least one accessory.

14. The system of claim 1, wherein the at least one rail system includes at least one of a rail and a slot spanning the length of the frame insert, the rail system configured to slidably couple to at least one of a corresponding slot and a corresponding rail mounted on at least one of an end structure and an accessory.

15. The system of claim 14, wherein the corresponding slot includes at least one of a bearing, a cushion, and a guide.

16. A configurable paving operations system, comprising: a modular framework having a transverse width and including at least a first frame insert and a second frame insert, each frame insert having a first end including a connector and a second end including a connector, and at least one rail system along its length, the second end of the first frame insert removably coupled to the first end of the second frame insert via connector;

at least a first end structure and a second end structure, the first end structure coupled to the first end of the first frame insert and the second end structure at least one of coupled to the second end of the second frame insert and slidably coupled to the modular framework via the at least one rail system;

each end structure having at least an attachment plate coupleable to a frame insert via connector, at least a first adjustable leg and a second adjustable leg coupled to the end structure, and a plurality of steerable crawlers including at least a first steerable crawler rotatably coupled to the first adjustable leg and a second steerable crawler rotatably coupled to the second adjustable leg; each end structure including a steering assembly operatively coupled to the plurality of steerable crawlers, con-

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figured to rotate at least one of the first steerable crawler and the second steerable crawler;

a control system including:

(i) at least one accessory removably coupled to the modular framework selected from the group including at least one of the following: a cure tank, an engine console, a walkway, an operating platform, a sensor operably coupled to the control system, an undercarriage, a hydraulic height adjuster configured to at least one of raise and lower the undercarriage through a vertical range; a texture rake, a texture broom, a texture drag, a spray bar assembly, a roller, an auger, a spreader, a trimmer, a form, a mold, a pan, a finisher, a saw, a bar inserter, a screed, a placer, a conveyor, and a plow;

(ii) at least one sensor mounted to at least one of the undercarriage, the hydraulic height adjuster, and the at least one accessory; and

(iii) at least one proximity sensor mounted to the at least one accessory.

17. A method for extending the width of a paving operations system having a modular framework including at least a first frame insert and a second frame insert, at least one rail system spanning the modular framework, at least a first end structure mounted to the first frame insert and a second end structure, the first end structure and the second end structure both having an inner end, an outer end, and a front adjustable leg operably coupled to a front steerable crawler and a rear adjustable leg operably coupled to a rear steerable crawler, the paving operations system including at least one component operably coupled to a control system, comprising:

securing the machine for extension;

connecting a third frame insert to the second frame insert; disconnecting at least one of a service connection and a hydraulic hose coupling the at least one component to the control system;

rotating at least the front steerable crawler and the rear steerable crawler of the second end structure to an orientation substantially parallel to the modular framework;

directing the second end structure transversely along the rail system until the outer end of the second end structure is flush with the third frame insert;

connecting at least one of a connection and a hydraulic hose coupling the at least one component to the control system;

rotating the at least the front steerable crawler and the rear steerable crawler of the second end structure to an orientation substantially perpendicular to the modular framework; and

securing the machine for operation.

18. A method for reducing the width of a paving operations system having a modular framework including at least a first, second, and third frame insert, at least one rail system spanning the modular framework, at least a first end structure mounted to the first frame insert and a second end structure, the first end structure and the second end structure both having an inner end, an outer end, a front adjustable leg operably coupled to a front steerable crawler and a rear adjustable leg operably coupled to a rear steerable crawler, the paving operations system including at least one component operably coupled to a control system, comprising:

securing the machine for retraction;

disconnecting at least one of a service connection and a hydraulic hose coupling the at least one component to the control system;

rotating at least the front steerable crawler and the rear  
steerable crawler of the second end structure to an ori-  
entation substantially parallel to the modular frame-  
work;  
directing the second end structure transversely along the 5  
rail system until the outer end of the second end structure  
is flush with the second frame insert;  
disconnecting the third frame insert from the second frame  
insert;  
connecting at least one of a connection and a hydraulic 10  
hose coupling the at least one component to the control  
system;  
rotating at least one of the front steerable crawler and the  
rear steerable crawler of the second end structure to an  
orientation substantially perpendicular to the modular 15  
framework; and  
securing the machine for operation.

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